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C H E M I S T R Y,

Exhibiting the present State of the Theory and Practice of that Science, its Application to NATURAL PHILOSOPHY, the PROCESSES OF MANUFACTURES, METALLURGY, and numerous other Arts dependant on the Properties and Habitudes of Bodies, in the MINERAL, VEGETABLE, and ANIMAL KINGDOMS.

WITH A

CONSIDERABLE NUMBER OF TABLES,

Expressing the Elective Attractions, Specific Gravities, Comparative Heats, Component Parts, Combinations, and other Affections of the Objects of Chemical Research.

ILLUSTRATED WITH ENGRAVINGS.

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By WILLIAM NICHOLSON.

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IN TWO VOLUMES.

V O L. II.

LONDON:

PRINTED FOR G. G. AND J. ROBINSON, PATERNOSTER-ROW.

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CH E M I S T R Y

the fact that the properties of the material are dependent on the properties and the manner of the treatment of the material. The properties of the material are dependent on the properties and the manner of the treatment of the material. The properties of the material are dependent on the properties and the manner of the treatment of the material.



THE UNIVERSITY OF CHICAGO

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BY WILLIAM NICHOLSON

IN TWO VOLUMES

W. H. G. V.

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*Refining and cupellation of the silver.*

The amalgams, according to their coppery or leady appearance, or to their purity, are either refined by cupellation, or simply melted down, and run into ingots.

When containing no gold, they may be delivered to the mint, without further fusion or cupellation, notwithstanding their copper alloy; but if auriferous and coppery, then they must be refined, or put to cupellation, that the copper may be destroyed, and the auriferous silver be brought to the standard of 15 loth 15 grains *per marc*, in which it is received at the mint.

*Distillation of the quicksilver, separated from the amalgam by heat or pressure.*

The quicksilver, separated by heat from the amalgam, contains some of the noble metals which passed with it through the pressing-bag. This generally amounts to 3—4, or one ounce per cwt. But this quicksilver being constantly in hand, and always serving in the subsequent triturations, its contents of gold and silver need only to be ascertained once at the annual balance of the accounts. This may be done, in small assays, by distilling the quicksilver, with granulated lead, in glass retorts; but the operation succeeds best in tubulated iron retorts, with cast iron receivers, filled with water, and luted to the necks of the retorts. Each of these is sunk half into the furnace, with its neck much inclined into the receivers. They are filled with two cwt. of quicksilver, to which is added 1—2, or one pound of granulated lead. The tubulated opening of the retort, and the neck of the receiver, must be carefully luted with refractory clay. The fire should be brisk, and the whole body of the retort be covered with the burning fuel. The quicksilver rises up in the form of vapour, and passes over into the receiver, where it is condensed, collected into drops, and falls to the bottom of the water. All the auriferous silver remains behind united with the lead, which, if it should stick to the bottom of the retort, may be melted in it by a coal-fire, and poured out into an ingot, to be afterwards put to the test or cupellation.

*Further treatment and use of the triturated residua, which have gone through the process of amalgamation.*

The residua commonly contain some gold and silver, more or less, according as they were well or badly pulverized, calcined, sifted, triturated, and washed. If the residuum should contain more than one ounce per cwt. and raw uncalcined particles appear in the same, it will be adviseable to calcine it once more with an addition of four per cent. of salt, and to let it undergo a second amalgamation. If it should be of an equal size, and perfectly calcined, it should be mixed up with new stuff, or triturated once more alone.

If, on the contrary, the residuum is silvery, in consequence of the imperfect washing and separation of the quicksilver and amalgam, it must be washed over again, more abundantly diluted with water.

The lixivia containing copper are precipitated by iron.

The Editors of the Chemical Journal add the following remarks, in a note, on the cold amalgamation:

Considering the complex apparatus for the warm amalgamation, the wear and loss of the copper boilers, the unequal produce, and the expence of firing (all which are now avoided), the cold amalgamation is, as Mr. Raspe observes, a noble improvement of the process. It was what Baron Born always aimed at, though his attempts were unsuccessful. Mr. Gellert, at Freyberg, first succeeded in it, using wooden cylindrical churns with perpendicular pistons, laid over with copper-



sheeting, which, by a quick motion up and down, produce a stronger trituration than the rotatory horizontal motion of barrels, and at the same time prevents the possibility of producing sublimate, or mercurius dulcis, by the excess of marine acid acting upon the quicksilver, to which that acid has less affinity than to copper. His first experiment was attended with uncommon success; for, by cold churning, he extracted the silver from pulverised ore, which contains but three ounces and a quarter per quintal, in the course of 16 hours, so completely that the leavings contained but two dwts. (The operation may even be finished in 10 hours, which otherwise required 24). Upon these principles the churning apparatus, in wooden cylinders, has been adopted in Bohemia, with a perforated cast iron piston, which by a crank motion moves quickly up and down. Though the whole is put in cold, yet, at the end of the operation, it heats in consequence of the quick trituration and motion of the pistons.

At Freyberg this cold amalgamation is performed in a mill which turns eight large barrels, each holding  $10\frac{1}{2}$  quintals of ore. The ores are dressed to contain four ounces per quintal, mixed with 10 per cent. of salt, and calcined and sifted in Baron Born's manner. When put into the barrels, one-fourth per cent. of quick-lime, and 34 lbs. of water are added, and turned briskly two hours, 36 turns per minute. The lime absorbs the excess of acids. To counteract the decomposition of metallic vitriols, and the precipitation of silver particles (which an excess of lime might occasion), after two hours turning, two per cent. of thin rolled iron chips, two inches square, are thrown into the barrels, and turned with the same two hours. Then the quicksilver, half a quintal to one quintal of ore, is added, together with an additional four per cent. of iron chips, previously coated with a little copper, by immersion in copper water, in order to prevent the dispersion of the quicksilver, and to catch and attract its smallest particles. After these last coppery-iron chips and the quicksilver have been added, the barrels are turned slower, at the rate of 20 or 25 turns per minute. After 12 hours turning, all the silver is extracted, except  $1\frac{1}{4}$  dwt. per quintal, which cannot be further extracted by amalgamation.

**ORES OF IRON.** When we consider the great destructibility of iron by the disengaged acids, and other uncombined agents in nature; it is not to be expected that much native iron should be found. We have however indubitable accounts of its existence. The most remarkable mass of this sort was discovered in Siberia, by Professor Pallas, which weighed 1600 pounds. Specimens of this have been sent to all parts of Europe. It is of that species called red short, being malleable while cold, but brittle when red hot.

It can hardly be doubted, but that this great mass of iron, brought by Pallas from Siberia into Europe, is the produce of nature. Its composition resembles that of forged iron; for a centenary (= 63 grains) yielded Bergman, by means of the muriatic acid, 49 cubic inches of inflammable air; and from many experiments it is found that ductile iron yields from 48 to 51 of the same inches\*.

Margraff, quoted by Fourcroy, found some of this kind of iron, in the form of ridges, at Ebenstock (or Eibenstock) in Saxony.

Native iron has been found, in a cubical form, at Senegal in Africa, out of which the black inhabitants make various vessels for their own use; also at

\* Magellan, in consequence of having examined this specimen of native iron, gives it as his opinion that it is a real volcanic production; but Professor Pallas expressly observes (*Journal de Physique, Supplement, tom. xiii. for 1778, p. 128.*) that the country where it was found affords not the least volcanic indication.

Eibenstock, on the margravate of Misnia, in the Upper Saxony, and at Stiria, in the circle of Austria. Some native irons have been found in a polyedral granulated form, and of a bright yellow colour, which on being polished shew their proper metallic colour; these two species of native iron are mentioned by Wallerius, in his Spec. 321.

Monet, quoted by Mongez, mentions a piece of many pounds weight, that has all the qualities of a good iron, and is kept in the collection of the College of the Mines at Freyberg. Other specimens have been found also of the kind near Bareith, which were malleable: and, lastly, the same Mongez mentions three specimens of native iron, kept in the King's cabinet in the Royal Garden at Paris; one of which was found at Kaumsdorf, in Thuringia; this is surrounded by an ore of the hepatic iron, and has a cavity with some protuberances of a brown hematites. The other two are from the native iron found by Pallas on the Emir Mountains of Siberia.

Bergman considers mispickel as a mixture of native iron and arsenic. For a description of this ore, see MISPICKEL. It is called Pierre de Santé by the French, but for what reason I know not, and is cut for toys. Twenty or thirty years ago a mineral was in common use for this purpose in England. The small stones or pieces were called marcasites, and were, I suppose, mispickel.

Wolfram is enumerated among iron ores, though never wrought as such. Mess. De Luyarts found only  $13\frac{1}{2}$  per cent. of iron. See WOLFRAM.

The magnet, or loadstone, is an ore containing iron approaching to the metallic state. It has not been much examined, probably on account of the heterogeneous nature of the various stones called by this name. Magnetism is their characteristic property, but they may nevertheless differ exceedingly in their contents, so as scarcely to come under the same mineralogical arrangement. Some contain as much as 75 per cent. of iron. See LOADSTONE, MAGNET, and MAGNETISM.

The black iron ore, or steel ore, is ponderous, of a very dark-gray colour, or rather slate black, and affords a black powder when scraped. Some specimens, however, afford a red powder. It is readily attracted by the magnet. Its fracture exhibits grains more or less fine, or else scales or facets, whence it has been improperly called galena of iron. When exposed to heat it gives scarcely any smell, and changes its colour very little, though its shining appearance goes off. A strong heat renders it partly malleable. It gives fire with steel, in consequence of a proportion of quartz it contains. Acids act upon it to a certain degree, but the iron is too much calcined to afford many crystals with the vitriolic acid.

That species of black iron ore, which has the form of octahedrons, nearly resembles the foregoing in its properties.

The calciform ores of iron are in general considered to be formed by deposition. Mongez reduces them to six principal species: 1. Ochres. 2. Earthy or bog ores. 3. Crystallized ore of the Isle of Elba. 4. Hematites. 5. Specular iron ore, and 6. Emery.

The ochres are very common, and appear to have been produced by the decomposition of pyrites; see OCHRES. There are two varieties: 1. Yellow ochre: this becomes red by calcination. 2. Red ochre. Both these are so common, and so much used in the arts, that it is scarcely requisite to describe the great variations of colour and consistence the several specimens possess.

Earthy, argillaceous, or bog ores of iron, are of different colours, reddish, yellowish brown, and sometimes gray, especially after exposure to the air for a



time. Internally they have a blueish-gray or iron colour. This ore is brittle, and resembles scorïæ, or small rounded or flattened stones, not obedient to the magnet, and in general of inconsiderable hardness. It mostly abounds with foreign sandy argillaceous or calcareous matters.

The crystallized iron ore of the island of Elba is one of the most beautiful of minerals. It has not yet been found except in that island. It is found in different states, in ochres of every shade, in the argillaceous sandy ore, in crystallized ore, and in hematites. The crystallized is the most common, the purest, and most beautiful. Its form, as well as colour, varies much. The shades are green, red, black, yellow, brown, blue, and violet; and some exhibit all the various and lively colours of precious stones, though this brilliant appearance becomes tarnished by the moisture of the air. This ore is very ponderous and hard, and frequently mixed with copper pyrites. Acids do not attack it, neither is it affected by the magnet, at least while in the mass: I do not find that this ore has been well analysed. Some writers pretend that sulphur is the mineralizer, and others fixed air; but from its great resemblance to the combination of iron with water in the experiment of the gun barrel (see AIR INFLAMMABLE), it appears likely that that fluid, as one of its principles, enters into the iron ore of the Isle of Elba.

Hematites exists in considerable abundance in the iron mines of ancient formation. It is formed in the manner of stalactites and stony concretions. In general it possesses considerable hardness, so as sometimes to give fire with steel. The varieties are, 1. Blackish hematites; fracture, vitreous, and sometimes shining; texture, fibrous or striated; colour brown black, but reddish when pounded. It gives fire with steel, becomes darker coloured, and as it were scaly, by ignition.—2. Red hematites. This is chiefly entitled to the name of blood-stone, from its colour. It is very heavy, ponderous, striated, and as if crystallized, or in small globules, called kidney ore.—3. Yellow hematites. This differs from the preceding, from the degree of the calcination of its metallic part, in the same manner as yellow ochre differs from red.

The specular iron ore, mentioned by Mongez among the calciform ores of iron, is easily distinguished by its brilliant facets, which often resemble polished steel. It is distinguished from the iron ore of Elba by a small portion of sulphur which it contains. It is plentifully found at Mount D'Or in Auvergne.

Emery is an ore of iron, which has the appearance of a very compact granular stone, of a blackish, grayish, or brown colour. By calcination it becomes brown or red, and, as Mongez says, harder than before. Kirwan thinks it to be a mixture of the red and white calces of iron with some unknown stony substance, perhaps tripoli. It is used as a grinding and polishing powder, and is scarcely inferior in hardness to any substance but the diamond. Its specific gravity is from 3,008 to 4,000. The best sort is of a dark gray colour. It is never wrought as an iron ore.

The white or sparry iron ore, or stahlstein of the Germans, consists, according to Bergman, of the brown calx of iron united with the white calx of manganese, and mild calcareous earth, in various proportions. Bayen\* examined a specimen from Germany of the best steel ore, and found it contain two-thirds iron, and the rest fixed air, except a small portion of zinc. The figure of this ore is either irregular or rhomboidal; frequently transparent; its texture scaly, lamellar, granular, or cellular. Sometimes it possesses a stalactitical form,

\* Journal de Phys. vii. 213. As this chemist did not reduce his iron beyond the state of a magnetic powder, I think he overlooked the nickel, which is magnetic, like iron, and also affords a green salt with vitriolic acid.

and is sometimes found in blackish brown powder. Its colour, when fresh dug, is whitish, but by exposure to the air it becomes gray, brown, reddish, yellowish, or black. Its specific gravity is from 3.6 to 4.0. It does not give fire with steel, unless by virtue of particles of quartz or pyrites, with which it is frequently interspersed. In the fire it decrepitates, grows black, becomes magnetic, and loses about one-third of its weight by the extrication of fixed air. One hundred parts of this ore from Eisenartz, in Stiria, afforded Bergman 38 of the brown calx of iron, 24 of the white calx of manganese, and 38 of mild calcareous earth. The iron answering to this quantity of calx is about 32 parts or one-third of the whole.

Iron mineralized by sulphur is mostly distinguished by the name of pyrites. It seldom contains iron in sufficient quantity to be extracted with profit, not only because a long continued heat is required to drive off the last portions of sulphur, but likewise because the iron usually proves of a bad quality. This ore has various degrees of hardness and consistency; is of a pale yellow colour, sometimes approaching that of gold, a circumstance which, added to its considerable weight, often attracts the attention of the unskilful, who imagine it to contain gold. It gives plenty of sparks with the steel, and emits an odour of sulphur. In the fire it cracks or decrepitates, burns with a blue flame, and assumes a dull brown colour: in the air it effloresces, is decomposed, its sulphur becomes acidified, unites with the iron and clay which are present in its composition, and with these forms vitriol and alum, for the obtaining both of which this mineral is wrought. Its varieties are, 1. In irregular masses. 2. In balls of various sizes disseminated in chalk. 3. In stalactites. 4. In cubes, frequently found in clay. 5. In hard crystals called marcasite.

The brown or reddish-brown ferruginous pyrites is called the hepatic iron ore. It is either spherical, or in cubes, or other regular forms: has no metallic lustre, does not easily give fire with steel, and is incapable of vitriolization. It contains much less sulphur and more iron than the yellow pyrites, but the metal it yields is brittle.

Gray iron ore has a shining metallic appearance, and commonly gives fire with steel. It is not at all magnetic, and, when scratched, gives a red trace. It yields from 40 to 66 per cent. of cold short iron. This property is derived from phosphorus, or its acid, which exists in the ore.

There are two ores of iron which contain plumbago united with iron. One is shining black, of a scaly texture, and more or less magnetic, called black Eisen Rahm or glimmer, by the Germans: the other is red, and differs from the preceding only in not being magnetic before calcination.

A blue combination of iron is found interspersed in clays in Finland, Scania, and elsewhere. Bergman calls it Native Prussian Blue. Sometimes the clays have a blue colour at their surface, and sometimes they assume that colour soon after being dug out of the ground. It is easily seen that the ore is ferruginous, and highly loaded with combustible matter; for it burns with a flame, and becomes red and magnetical. A mild heat renders this substance green, and a stronger converts it into black scoria. Alkalis, as well as acids, dissolve this blue powder, and destroy its colour, which nevertheless appears again when precipitated from an acid by an alkali, or by an alkali from an acid; but commonly it is greenish, and soon becomes white. If an infusion of tea or nut galls be poured on this whitish sediment, it resumes its first colour. From these details it appears, as Bergman remarks, that this blue, though analogous to



to the artificial Prussian blue, differs nevertheless from it in intensity, by the manner of its production and other peculiar qualities. It preserves its colour in water, but becomes black in oils.

For the methods of analysis of the ores of iron, as well as its chemical properties and several states, see the article IRON. But from the extensive importance of this metal, I shall here add the methods of treatment in the large way, from Keir's notes to Macquer's Dictionary, article SMELTING.

Most ores of iron require to be roasted previously to their fusion; some more slightly, and others with a more violent and longer continued fire. Those which contain much sulphur, arsenic, or vitriolic acid, require a long continued and repeated roasting, that the volatile matters may be expelled. Of this kind is the black iron ore, from which the Swedish iron is said to be obtained.

Some ores require a very slight roasting, only that they may be dried and rendered friable; such are the ores called bog ores: and others, which being in a calcined state, and containing little sulphureous matter, would, by a further calcination, be rendered less capable of being reduced to a metallic state.

The roasting of ores of iron is performed by kindling piles, consisting of strata of fuel and of ore placed alternately upon one another, or in furnaces similar to those commonly employed for the calcination of lime-stone.

The next operation is the fusion or smelting of the ore. This is generally performed in furnaces or towers from 20 to 30 feet high, in the bottom of which is a basin for the reception of the fluid metal. When the furnace is sufficiently heated, which must be done at first very gradually, to prevent the cracking of the walls; a quantity of the ore is to be thrown in, from time to time, at the top of the furnace, along with a certain quantity of fuel and of lime-stone, or whatever other flux is employed. While the fuel below is consumed by the fire excited by the wind of the bellows, the ore, together with its proportionable quantity of fuel and of flux, sink gradually down, till they are exposed to the greatest heat in the furnace. There the ore and the flux are fused, the metallic particles are revived by the fuel, are precipitated by means of their weight through the scoria formed of the lighter earthy parts of the flux and of the ore, and unite in the basin at the bottom of the furnace, forming a mass of fluid metal covered by a glassy scoria. When a sufficient quantity of this fluid metal is collected, which is generally twice or thrice in 24 hours, an aperture is made, through which the metal flows into a channel or groove made in a bed of sand; and from thence into smaller lateral or connected channels, or other moulds. There it is cooled, becomes solid, and retains the forms of the channels or moulds into which it flows. The piece of iron formed in the large channel is called a sow, and those formed in the smaller channels are called pigs. Sometimes the fluid iron is taken out of the furnace by means of ladles, and poured into moulds, ready prepared, of sand or of clay, and is thus formed into the various utensils and instruments for which cast iron is a proper material.

The scoria must be from time to time allowed to flow out, when a considerable quantity is formed, through an aperture made in the front of the furnace for that purpose. A sufficient quantity of it must, however, be always left to cover the surface of the melted iron; else the ore which would fall upon it, before the separation of its metallic from its unmetallic parts, would lessen the fluidity and injure the purity of the melted metal. This scoria ought to have a certain degree of fluidity; for if it be too thick, the revived metallic particles will not be able to overcome its tenacity, and collect together into drops, nor be precipitated. Accordingly,

Accordingly, a scoria, not sufficiently fluid, is always found to contain much metal. If the scoria be too thin, the metallic particles of the ore will be precipitated before they are sufficiently metallized, and separated from the earthy and unmetallic parts. A due degree of fluidity is given to the scoria, by applying proper heat, and by adding fluxes suited to the ore.

Some ores are fusible without addition, and others cannot be smelted without the addition of substances capable of facilitating their fusion.

The fusible ores are those which contain sulphur, arsenic, or are mixed with some fusible earth.

The ores difficultly fusible are, those which contain no mixture of other substance. Such are most of the ores which contain iron in a state nearly metallic. As iron itself, when purified from all heterogeneous matters, is scarcely fusible without addition, so the metal contained in these purer kinds of ores cannot be easily extracted without the addition of some fusible substance. 2. Those which are mixed with some very refractory substance. Some of these refractory ores contain arsenic; but as this substance facilitates the fusion of iron, we may presume that their refractory quality depends upon a mixture of some unmetallic earth or other unfusible substance. The earth which is mixed with the common calciform ores is in considerable quantity, and is sometimes calcareous, sometimes siliceous, and sometimes argillaceous.

Keir thinks it probable that the fusibility of some ores may greatly depend on the degree of calcination to which the metal contained in them has been reduced; since we have reason to believe, that, by a very perfect calcination, some metals, at least, may be reduced to the state of an earth almost unfusible, and scarcely capable of reduction; and since we know, that in every calcination and subsequent reduction of a given quantity of any imperfect metal, a perceptible part of that quantity is always lost or destroyed, however carefully these operations may have been performed. That some of these ores are already too much calcined, appears from the instance above-mentioned of the bog ores, which are injured by roasting; and even the great height of the common smelting furnaces, although advantageous to many ores that require much roasting, is said to be injurious to those which are already too much calcined, by exposing them to a further calcination, during their very gradual descent, before they arrive at the hottest part of the furnace, where they are fused.

But, as too violent calcination renders some ores difficultly fusible; so, too slight calcination of other ores injures the purity of the metal, by leaving much of the sulphureous or other volatile matter, which ought to have been expelled.

Various substances are added to assist the fusion of ores difficultly fusible. These are: 1. Ores of a fusible quality, or which being mixed with others of a very different quality, become fusible: accordingly in the great works for smelting ores of iron, two or more different kinds of ores are commonly mixed, to facilitate the fusion, and also to meliorate the quality of the iron. Thus an ore yielding an iron which is brittle when hot, which quality is called red-short, and another ore which produces iron brittle when cold, or cold-short, are often mixed together; not, as is sometimes supposed, that these qualities are mutually destructive of each other, but that each of them is diminished in the mixed mass of iron, as much as this mass is larger than the part of the mass originally possessed of that quality. Thus, if from two such ores the mass of iron obtained consists of equal parts of cold-short and of red-short iron, it will have both these qualities, but will be only half as cold-short as iron obtained solely from one of the ores, and half



half as red-short as iron obtained only from the other ore. 2. Earths and stones are also generally added to facilitate the fusion of iron ores. These are such as are fusible, or become fusible when mixed with the ore, or with the earth adhering to it. Authors direct, that, if this earth be of an argillaceous or siliceous nature, limestone or some calcareous earth should be added; and that if the adherent earth be calcareous, an argillaceous or siliceous earth should be added; because these two earths, though singly unfusible, yet, when mixed, mutually promote the fusion of each other: but as lime-stone is almost always added in the smelting of iron ores, and as in some of these, at least, no argillaceous or siliceous earth appears to be contained, Keir is inclined to believe, that it generally facilitates the fusion, not merely by uniting with those earths, but by uniting with that part of the ore which is most perfectly calcined, and least disposed to metallization; since we know, that by mixing a calciform or roasted ore of iron with calcareous earth, without any inflammable matter, these two substances may be totally vitrified. See Experiments made upon Quick-lime, and upon Iron, by Mr. Brandt, in the Swedish Memoirs for the years 1749 and 1751. Calcareous earth does indeed so powerfully facilitate the fusion of iron ores, that it deserves to be considered whether workmen do not generally use too great a quantity of it, in order to hasten the operation. For when the scoria is rendered too thin, much earthy or unmetallized matter is precipitated, and the cast iron produced is of too vitreous a quality, and not sufficiently approximated to a true metallic state.

Some authors pretend, that a principal use of the addition of lime-stone in the smelting of iron ores is to absorb the sulphur, or vitriolic acid, of these ores: but, as we have already observed, a hepar of sulphur is formed by that mixture of calcareous earth and sulphur, which is capable of dissolving iron in a metallic state; and thus the quantity of metal obtained from an ore not sufficiently divested of its sulphur, or vitriolic acid, (which, by uniting with the fuel, is formed into a sulphur during the smelting) must be considerably diminished, though rendered purer by addition of calcareous earth: hence the utility appears, of previously expelling the sulphur and vitriolic acid from the ore by a sufficient roasting. 3. The scoria of former smeltings is frequently added to assist the fusion of the ore; and when the scoria contains much iron, as sometimes happens in ill-conducted operations, it also increases the quantity of metal obtained.

The quantity of these fusible matters to be added, varies according to the nature of the ore; but ought in general to be such, that the scoria shall have its requisite degree of thinness, as is mentioned above.

The fuel used in most parts of Europe for the smelting of ores of iron is charcoal. Lately, in several works in England and Scotland, iron ore has been smelted by means of pit-coal, previously reduced to cinders or coaks, by a kind of calcination similar to the operation for converting wood into charcoal, by which the aqueous and sulphureous parts of the coal are expelled, while only the more fixed bituminous parts are left behind. In France, pit-coal not calcined has been tried for this purpose, but unsuccessfully. The use of peat has also been introduced in some parts of England.

The quality of the iron depends considerably upon the quality, and also upon the quantity of the fuel employed. Charcoal is fitter than coaks for producing an iron capable of being rendered malleable by forging.

The quantity of fuel, or the intensity of the heat, must be suited to the greater or less fusibility of the ore. Sulphureous and other ores easily fusible require less

less fuel than ores difficultly fusible. In general, if the quantity of fuel be too small, and the heat not sufficiently intense, all the iron will not be reduced, and much of it will remain in the scoria, which will not be sufficiently thin. This defect of fuel may be known by the blackness and compactness of the scoria, by the qualities of the iron obtained, which in this case is hard, white, light, intermixed with scoria, smooth in its texture, without scales or grains, rough and convex on its surface, and liable to great loss of weight by being forged; and lastly, it may be known by observing the colour and appearance of the drops of metal falling down from the smelted ore, and of the scoria upon the surface of the fluid metal, both which are darker coloured than when more fuel is used. When the quantity of fuel is sufficiently large, and the heat is intense enough, the iron is darker coloured, denser, more tenacious, contains less scoria, and is therefore less fusible, and loses less of its weight by being forged. Its surface is also smoother and somewhat concave; and its texture is generally granulated. The scoria in this case is of a lighter colour and less dense. The drops falling from the smelting ore, and the liquid scoria in the furnace, appear hotter and of a brighter colour. When the quantity of fuel is too great, and the heat too intense, the iron will appear to have a still darker colour, and more conspicuous grains or plates; and the scoria will be lighter, whiter, and more spongy. The drops falling from the smelted ore, and the fluid scoria, will appear to a person looking into the furnace through the black hole to be very white and shining hot. The quantity of charcoal necessary to produce five hundred weight of iron, when the ore is rich, the furnace well contrived, and the operation skilfully conducted, is computed to be about forty cubic feet; but is much more in contrary circumstances.

The time during which the fluid metal ought to be kept in fusion before it is allowed to flow out of the furnace, must be also attended to. In some works the metal is allowed to flow out of the furnace every six or eight, and in others only every ten or twelve hours. Some workmen imagine, that a considerable time is necessary for the concoction of the metal. This is certain, that the iron undergoes some change by being kept in a fluid state; and that if its fusion be prolonged much beyond the usual time, it is rendered less fluid, and also its cohesion, when it becomes cold, is thereby greatly diminished. The quantity of iron daily obtained from such a furnace as is above described, is from two to five tons in 24 hours, according to the richness and fusibility of the ore, to the construction of the furnace, to the adjustment of the due quantity of flux and of fuel, and to the skill employed in conducting the operation.

The quality of the iron is judged by observing the appearances during its flowing from the furnace, and when it is fixed and cold. If the fluid iron, while it flows, emits many and large sparkles; if many brown spots appear on it while it is yet red-hot; if, when it is fixed and cold, its corners and edges are thick and rough, and its surface is spotted; it is known to have a red-short quality. If, in flowing, the iron seems covered with a thin glassy crust, and if, when cold, its texture be whitish, it is believed to be cold-short. M. Reaumur says, that dark-coloured cast-iron is more impure than that which is white. The Marquis de Courtivron is of a contrary opinion. But no certain rules for judging of the quality of iron before it be forged can be given. From brittle cast-iron, sometimes ductile forged-iron is produced. Cast-iron with brilliant plates and points, when forged, becomes sometimes red-short, and sometimes cold-short. Large shining plates, large cavities called eyes, want of sufficient density, are almost certain



marks of bad iron; but whether it will be cold or red-short cannot be affirmed till it be forged. Whiteness of colour, brittleness, closeness of texture, and hardness, are given to almost any cast-iron by sudden cooling; and we may observe, that in general the whiter the metal is, the harder it is also, whether these properties proceed from the quality of the iron, or from sudden cooling; and that, therefore, the darker coloured iron is fitter for being cast into moulds, because it seems capable of being filed and polished, especially after it has been exposed, during several hours, to a red heat in a reverberatory furnace, and very gradually cooled. This operation, called by the workmen annealing, changes the texture of the metal, renders it softer, and more capable of being filed than before, and also considerably less brittle.

It is in fact capable of being softened by annealing, and hardened by sudden cooling like steel, through the heat regained, for these changes are greater. Many artists avail themselves of this property to advantage. See IRON.

In Navarre, and in some of the southern parts of France, iron ore is smelted in furnaces much smaller, and of a very different construction from those above described. A furnace of this kind consists of a wide-mouthed copper caldron, the inner surface of which is lined with masonry a foot thick. The mouth of the caldron is nearly of an oval or elliptic form. The space or cavity contained by the masonry is the furnace in which the ore is smelted. The depth of this cavity is equal to two feet and a half; the larger diameter of the oval mouth of the cavity is about eight feet; and its smaller diameter is about six feet: the space of the furnace is gradually contracted towards the bottom, the greatest diameter of which does not exceed six feet: eighteen inches above the bottom is a cylindrical channel in one of the longer sides of the caldron and masonry, through which the nozzle of the bellows passes. This channel, and also the bellows-pipe, are so inclined, that the wind is directed towards the lowest point of the opposite side of the furnace. Another cylindrical channel is in one of the shorter sides of the furnace, at the height of a few inches from the bottom, which is generally kept closed, and is opened occasionally to give passage to the scoria; and above this is a third channel, in the same side of the furnace, through which an iron instrument is occasionally introduced to stir the fluid metal, and to assist, as is said, the separation of the scoria from it. The greatest height of this channel is at its external aperture on the outside of the furnace, and its smaller height is at its internal aperture, so that the instrument may be directed towards the bottom of the furnace; but the second channel below it has a contrary inclination, that when an opening is made, the scoria may flow out of the furnace into a basin placed for its reception. When the furnace is heated sufficiently, the workmen begin to throw into it alternate charges of charcoal; and of ore previously roasted. They take care to throw the charcoal chiefly on that side at which the wind enters, and the ore at the opposite side. At the end of about four hours a mass of iron is collected at the bottom of the furnace, which is generally about six hundred weight: the bellows are then stopt; and when the mass of iron is become solid, the workmen raise it from the bottom of the furnace, and place it, while yet soft, under a large hammer, where it is forged. The iron produced in these furnaces is of the best quality; the quantity is also very considerable, in proportion to the quantity of ore, and to the quantity of fuel employed. In these furnaces no lime-stone or other substance is used to facilitate the fusion of the ore. We should receive much instruction concerning the smelting of iron ore, if we knew upon what part of the process or circumstance the excellence of the iron

iron obtained in these furnaces depends; whether on the quality of the ore; on the disuse of any kind of flux, by which the proportion of vitreous or earthy matter, intermixed with the metallic particles, is diminished; on the forging while the iron is yet soft and hot, as the Marquis de Courtivron thinks; or on some other cause not observed.

To separate the impurities from cast-iron, and to unite the metallic parts more closely and compactly, and thus to give it the ductility and tenacity which render this metal more useful than any other, are the effects produced by the following operations:

The first of these operations is a fusion of the iron, by which much of its impurities is separated in form of scoria; and by the second operation, a further and more complete separation of these impurities, and also a closer compaction of the metallic particles, are effected by the application of mechanical force or pressure, by means of large hammers.

Some differences in the construction of the forge or furnace, in which the fusion or refining of cast-iron is performed, in the method of conducting the operation, and in some other circumstances, are observed to occur in different places. The following, extracted by Keir from Swedenborgius, is the German method.

The fusion of the cast-iron, which is to be rendered malleable, is performed upon the hearth of a forge similar to that used by blacksmiths: at one side of this hearth is formed a cavity or fire-place, which is intended to contain the fuel and the iron to be melted: this fire-place is twenty inches long, eighteen inches broad, and twelve or fourteen inches deep; it is bounded on three sides by three plates of cast-iron placed upright, and on the fourth side, which is the front, or that part nearest to which the workmen stand, by a large forge hammer, through the eye of which the scoria is at certain times allowed to flow. The floor also of the fire-place is another cast-iron plate. The thickness of these plates is from two to four inches. One of the upright side plates rests against a wall, in an aperture through which a copper tube, called the *turgere*, is luted with clay. This tube is a kind of case or covering for the pipe of a pair of bellows placed behind the wall, and its direction is therefore parallel to that of the bellows-pipe; but it advances about half a foot further than this pipe into the fire-place, and thus gives greater force to the air, which it keeps concentrated, or prevents the divergence of the air, till it is requisite to act. The tube rests upon the upper edge of the side-plate which leans against the wall, nearer to the back part than to the front of the fire-place, and in such an oblique direction, that the wind shall be impelled towards the furthest part of the floor of the fire-place, or where this floor is intersected by the opposite side-plate. The obliquity of the *turgere* ought to vary according to the quality of the iron: and therefore, in every operation it may be shifted till its proper position is found. The more nearly its direction approaches to a horizontal plane, the more intense is the heat; but a larger quantity of fuel is consumed than is even proportional to the increase of heat, because the flame is not then so well confined. When the iron is easily fusible, great heat is not required: the *turgere* may then decline considerably from the horizontal plane, and thus fuel may be saved. This *turgere*, though made of copper, a metal more easily fusible than iron, is preserved from fusion by the constant passage of cold air through it. It must be carefully kept open, and cleansed from the scoria, which would be apt to block its cavity, by which not only the heat



would be too much diminished for the success of the operation, but the tube itself would be melted.

To prepare for the fusion, a quantity of scoria of a former operation is thrown into the fire-place, till one-third part of this be full; and then the remaining two-thirds of the fire-place are to be filled with smaller scoria, coal-dust, and sparks ejected from hot iron. These matters, being fusible, form a bath for the reception of the iron when melted. Upon this bed of scoria the mass of cast-iron to be melted is placed; so that one end of it shall be within the fire-place, opposite to the turgere, and at the distance of about four or five inches from its aperture; and the other end shall stand without the fire-place, to be pushed in as the former is melted. The upper side of the mass of iron ought to be in the same horizontal plane as the upper part of the orifice of the turgere; that the wind may, by means of the obliquity of its course, strike upon and pass along the under-side of the mass: but if the iron be difficultly fusible, the turgere is to be disposed more horizontally, so that the wind shall strike directly upon the mass of iron; and that one part of the blast shall graze along the upper surface, and the other part along the under-surface of the iron. The mass of iron weighs generally from 200 to 400 pounds. Sometimes two or three smaller masses are put one above another, so as not to touch. When these are of different qualities, the cold-short piece is placed undermost, that being more unfusible than the red-short. The iron being placed, charcoal powder is thrown on both sides; and coals are accumulated above, so as to cover entirely the iron.

The coals are then to be kindled, and the bellows are made to blow, at first slowly, and afterwards with gradually increased force. The iron is liquefied by degrees, and flows down in drops through the melted scoria to the bottom of the fire-place; during which the workmen frequently turn the iron, so that the end opposed to the blast of wind may be equally exposed to heat, and uniformly fused. While the coals are consumed, more are thrown on, so that the whole may be kept quite covered. During the operation, a workman frequently sounds the bottom and corners of the fire-place, by means of a bar or poker, raises up any mass of metal which he finds adhering to these, and exposes them to the greatest heat, that they may be more perfectly fused.

When all the iron is fused, no more coals are to be added, but the melted mass is to remain half uncovered for some time; during which the iron boils and bubbles, and its surface swells and rises higher and higher. When the iron has risen as high as the upper-edge of the fire-place, the coals upon its surface must be removed; and by thus exposing it to cold air, its ebullition and swelling subside. In this state, or coction, the iron is kept during half an hour, or more, by adding occasionally pieces of good coal, which maintain a sufficient heat, without covering entire the surface of the mass. During this coction, the workmen allow the orifice of the turgere to be half stopped up by the scoria, that the air may not blow upon the iron with all its force, by which it would be too much cooled. Accordingly, when they think that the coction has continued sufficiently long, they clear the passage of the turgere, and the mass is soon cooled by the cold air: at the same time also, they open a passage in the eye of the hammer placed in the front of the fire-place, through which some of the scoria is allowed to flow out. When the iron has become solid, the bellows are stopt, the coals are removed, and the mass is left during an hour; and then the workmen raise it from the fire-place, turn it upside down, and proceed to the second coction or fusion of the iron.

For

For this second operation, the mass is to be so placed that one part of it shall rest upon the turgere, and the other upon the scoria remaining in the fire-place. This scoria is to be disposed in an oblique direction, parallel to the turgere, by which means the wind of the bellows is obliged to pass all along the under side of the mass of iron. About the sides of the mass, charcoal-powder and burnt ashes are thrown; but towards the turgere, dry and entire pieces of coals are placed to maintain the fire. When these are kindled, more coals are added, and the fire is gradually excited. The workman attends to the direction of the flame, that it pass equally along under the surface of the iron, quite to the further extremity, and that it do not escape at the sides, nor be reverberated back towards the turgere, by which this copper tube might be melted. During this fusion, pieces of iron are apt to be separated from the mass, and to fall down unfused to the bottom and corners of the fire-place. These are carefully to be searched for and exposed to the greatest heat till they are melted. When the whole mass is thus brought into perfect fusion, the coals are removed, and the wind blowing on its surface, whirls and dissipates the small remaining pieces of scoria, and sparks thrown out from the fluid iron. This jet of fire continues about seven or eight minutes, and the whole operation about two hours. In this second fusion the scoria is to be thrice removed, by opening a passage through the eye of the hammer. The first time of removing the scoria is about twenty minutes from the kindling of the fire; the second time is about forty minutes after the first; and the third time is near the end of the operation.

The mass is then removed from the hearth, and put upon the ground of the forge, where it is cleansed from scoria, and beat into a more uniform shape. It is then placed on an anvil, where, by being forged, it receives a form nearly cubical. This mass is to be divided into five, six, or more pieces, by means of a wedge; and these are to be heated and forged till they are reduced to the form of the bars commonly sold.

In some forges the iron is fused only once, and in others it suffers three fusions, by which it is said to be rendered very pure. Where only one fusion is practised, it is called the French method. In this no greater quantity of iron is fused at once than is sufficient to make one bar. The fire-place is of considerable less dimensions, and especially is less deep than in the German method above described. The fire is also more intense, and the proportion of fuel consumed to the iron is greater. The iron, when melted, is not kept in a state of ebullition, as is above described; but this ebullition is prevented by stirring the fluid mass with an iron bar, till it is coagulated and becomes solid.

By these operations, fusion and forging, the iron loses about  $\frac{2}{3}$  parts of its former weight, sometimes more, and sometimes less, according to the quality of the cast-iron employed; it is purified from the vitreous and earthy parts which were intermixed with it; its metallic particles are more closely compacted, its texture is changed, and it is rendered more dense, soft, and malleable, tough, and difficultly fusible.

The degrees, however, of these qualities vary much in different kinds of iron. Thus some iron is tough and malleable, both when it is hot and when it is cold. This is the best and most useful iron. It may be known generally by the equable surface of the forged bar, which is free from transverse fissures or cracks in the edges; and by a clear, white, small-grained, or rather fibrous texture. Another kind is tough when it is heated, but brittle when it is cold. This is called cold, short iron, and is generally known by a texture consisting of large shining plates, without



without any fibres. It is less liable to rust than other iron. A third kind of iron, called red-short, is brittle when hot, and malleable when cold. On the surface and edges of the bars of this kind of iron, transverse cracks or fissures may be seen; and its internal colour is dull and dark. It is very liable to rust. Lastly, some iron is brittle, both when hot and when cold.

Many authors assert that the red-short quality of iron proceeds from some sulphur or vitriolic acid being contained in it, because sulphur is known to produce this effect when added to iron, and because the iron obtained from pyritous and other sulphurated ores has generally this quality. It is with more probability asserted by others to arise from arsenic; but I know of no direct experiments which ascertain this fact.

The cause of the cold-short quality of iron is well ascertained to arise from the presence of phosphorus, or its acid.

In one bar frequently two or more different kinds of iron may be observed, which run all along its whole length; and scarcely a bar is ever found of entirely pure and homogeneous iron. This difference probably proceeds from the practice we have mentioned of mixing different kinds of ores together in the smelting, and also from the practice of mixing two or more pigs of cast-iron of different qualities in the finery of these; by which means the red-short and the cold-short qualities of the different kinds are not, as we have already remarked, mutually counteracted or destroyed by each other; but each of these qualities is diminished in the mixed mass of iron, as much as this mass is larger than the part of the mass originally possessed of that quality: that is, if equal parts of red-short and of cold-short iron be mixed together, the mixed mass will be only half as red-short as the former part, and half as cold-short as the latter. For these different kinds of iron seem as if they were only capable of being interwoven and diffused through each other, but not of being intimately united or combined.

The quality of forged iron may be known by the texture which appears on breaking a bar. The best and toughest iron is that which has the most fibrous texture, and is of a clear grayish colour. This fibrous appearance is given by the resistance which the particles of the iron make to their rupture. The next best iron is that whose texture consists of clear whitish small grains, intermixed with fibres. These two kinds are malleable, both when hot and when cold, and have great tenacity. Cold-short iron is known by a texture consisting of large shining plates, without fibres; and red-short iron is distinguished by its dark dull colour, and by the transverse cracks and fissures on the surface and edges of the bars. The quality of iron may be much improved by violent compression, as by forging and rolling, especially when it is not long exposed to too violent heat, which is known to injure, and at length to destroy, its metallic properties.

The following processes are sufficient to direct the assay of iron ores in the furnace.

#### PROCESS I.

(Extracted from Cramer's Art of Assaying, process 54.)

*To reduce or precipitate iron out of its ore in a close vessel.*

Roast for a few minutes in a test under a muffle, and with a pretty strong fire, two centners of the small weight of your iron ore, grossly pulverised, that the volatile matters may be dissipated in part, and the ore itself be softened in case it should be too hard. When it is grown cold, beat it extremely fine, and roast it a second time, as you do the copper ore, but in a much stronger fire, till it no longer emits any smell; then let it grow cold again. Compose a flux of three parts

parts of the white flux, with one part of fusible pulverised glass, or of the like sterile unfulphureous scorias, and add sandiver and coal-dust, of each one-half part; add of this flux three times the quantity of your roasted ore, and mix the whole very well together; then choose a very good crucible, well rubbed with lute within, to stop the pores which may remain in different places unseen; put into it the ore mixed with the flux; cover it over with common salt, and shut it close with a tile, and with lute applied to the points.

Put the wind-furnace upon its bottom part, having a bed made of coal-dust. Introduce besides into the furnace, a small grate supported on its iron bars, and a stone upon it, whereon the crucible may stand, as on a support; surround the whole with hard coals, not very large, and light them at top: when the vessel begins to grow red, which is indicated by the common salts ceasing to crackle, stop with gross lute the holes of the bottom part of the furnace, except that in which the nozzle of the bellows is received; blow the fire, and excite it with great force, adding now and then fresh fuel, that the vessel may never be naked at top: having thus continued your fire in its full strength for three quarters of an hour, or for a whole hour, in the next place take the vessel out of it, and strike several times the pavement upon which it is set, that the small grains of iron which happen to be dispersed may be collected into a regulus, which you will find after having broken the vessel.

When the regulus is weighed, try its malleability; then make it red hot, and when it is so, strike it with a hammer: if it bears the strokes of a hammer, both when red-hot and when cold, and extends a little, you may pronounce your iron very good; but if, when either hot or cold, it proves brittle, you may judge it to be not quite pure, but still partly mineralized.

*Remarks.* The arsenic, but especially the sulphur, must be dissipated by roasting; for the former renders the iron brittle, and the latter not only does the same, but being managed in a close vessel, with a saline alkaline flux, turns to liver of sulphur; which acts strongly upon the iron, and prevents its reduction: so that the whole, or a great part of it at least, is retained by the sulphureous scoria; in this case therefore it is generally in vain to look for a regulus.

The iron obtained from this first precipitation has scarcely ever the requisite ductility, but is rather brittle: the reason of which is, that some of the sulphur and arsenic remain in it; for, notwithstanding that the greatest part of these is dissipated by roasting, yet some part adheres so that it can never be separated, but with absorbent terrestrial alkaline ingredients, that change the nature of the sulphur. For which reason, in larger operations, they add quicklime, marble, or other lime stones; which, while they absorb these minerals, are by it, and by means of the destroyed part of their iron, brought to a fusion, and turn to a vitrified scoria, although in other circumstances they naturally very much resist a vitrification. Another cause of the brittleness of iron is the unmetallic earth, when it is not yet separated from it; for the iron ore contains a great quantity of it, and in the melting remains joined with the reguline part: whence the iron is rendered very coarse and brittle. Some iron ores are altogether untractable; and yet the reguli produced out of them, when broken, have sometimes a neat semi-metallic appearance, which undoubtedly proceeds from a mixture of a small quantity of some other metal or semi-metals.



## PROCESS II.

*The following process for assaying iron ores, and ferruginous stones and earths, is extracted from Gellert's Elements of Assaying.*

Roast two quintals of iron ore, or of ferruginous earth: divide the roasted matter into two equal parts; to each of which add half a quintal of pulverised glass, if the substance be fusible, and contain much metal; but if otherwise, add also half a quintal of calcined borax. If the roasting has entirely disengaged the sulphur and arsenic, an eighth part, or even half a quintal of quicklime may be added. With the above matters mix 12 pounds of charcoal powder.

Take a good crucible, and cover the bottom and sides of its inner surface with a paste made of three parts of charcoal dust, and one part of clay beat together; in the hollow left in this paste put the above mixture, press it lightly down, cover it with pulverised glass, and put on the lid of the crucible.

Place two such crucibles at the distance of about four fingers from the air-pipe, in such a manner that the air shall pass betwixt them at about the third part of the height from the bottom; fill the space between the two crucibles with coals of a moderate size; throw lighted coals upon them, that the fire may descend, and make them red-hot from top to bottom; at first let the bellows blow softly, and afterwards strongly during an hour, or an hour and a quarter; then take away the crucible, and break it when cold. A regulus will be found in the bottom, and sometimes some small grains of iron in the scoria, which must be separated and weighed along with the regulus; then try the regulus, whether it can be extended under the hammer, when hot and when cold.

*Remarks.* To disengage a metal from the earthy matters mixed with it by fire, we must change these matters into scoria or glass. This change may be effected by adding some substance capable of dissolving these matters; that is, of converting them into a scoria or glass, from which the metallic matters may, by their weight, separate and form a regulus at bottom. Fixed alkali, which is an ingredient of the black and of the white flux, is a powerful solvent of earths and stones: but the alkali (by the assistance of sulphur) does also dissolve iron, especially when this metal is in a calcined or earthy state; and the solution is so much more complete, as the fire is longer applied. Hence, in ordinary assays, where an alkaline salt is used, little or no regulus of iron is obtained. Now, glass acts upon, and dissolves earths and stones; but not, or at least in a very small degree, iron; consequently glass is the best flux for such assays; and experience confirms this assertion. If the ore contains but little iron, we may also add to the glass some borax; but borax cannot be employed singly, because it very soon fuses and separates from the ore before the metal is revived. Quick-lime is added, not only to absorb the sulphur and arsenic remaining in the ore, but also because it dissolves and vitrifies the stony and earthy matters of iron ores, which are generally argillaceous. For which reason, in the large operations for smelting iron ore, quicklime, and even, in certain cases, gypsum, are commonly added to facilitate the fusion.

The reduction of iron ore, and even the fusion of iron, require a violent and long continued heat; and therefore, in this operation, we must not employ an inflammable substance; as pitch, that is soon consumed; but charcoal pulverised, which in close vessels is not sensibly wasted. Too much charcoal must not be added, else it will prevent the action of the glass upon the earthy matter of the ore, and consequently the separation of the metallic part. Experiments convinced

vinced Cramer, that one part of charcoal-dust to eight parts of ore was the best proportion.

When iron is surrounded by charcoal, it is not decomposed or destroyed: hence the iron of the ore, which sinks into the hollow made of paste of charcoal-dust and clay, remains there unhurt. The clay is added in this paste to render it more compact, and to keep the fluid iron collected together.

The air is directed between the crucibles, because, if it was thrown directly upon them, they would scarcely be able to resist the heat. The space between the air-pipe and the crucibles ought to be constantly filled with charcoal, to prevent the cold air from touching the crucibles. Ductile and malleable iron is seldom obtained in this first operation. The sulphur and arsenic, and frequently likewise an earthy matter adhering to the iron, prevent these qualities.

For other particulars respecting the properties of iron, and the treatment of its ores, see IRON.

**ORES OF LEAD.** Lead has been found native in various parts of England and elsewhere, or at least in the metallic state. But most mineralogists question the existence of native lead, and consider the specimens produced as such, to be either the produce of ancient founderies, or purer kinds of lead ore. Hence we may conclude that the unequivocal specimens of native lead are scarce; but the curious specimen mentioned by Bomare, in the second volume of his Mineralogy, quoted by Magellan, appears to be decisive in favour of the existence of this metal in a native state. It was in the collection of the Abbé Nollin at Paris, and came from the lead mines of Pompean, near Rennes, in Brittany. This metal was very malleable, could be cut with a knife without crumbling, and easily melted over the flame of a candle. It weighed about two pounds; was imbedded in an earthy lead ore of a reddish colour, and had a flaty vein that went through it.

Lead is found mineralized by the vitriolic acid. According to Mr. Monnet, who calls this the pyritous ore of lead, it sometimes occurs in the form of a white ponderous calx, soluble in 16 or 18 times its weight of water. It does not effervesce, nor is soluble in other acids; it may be reduced by laying it on a burning coal. It originates from the spontaneous decomposition of sulphurated lead ores. Mon. Mineral. 371. According to Dr. Withering, quoted by Kirwan, it is found in great quantity in the island of Anglesea, but united to iron, and not reducible by the blow-pipe or charcoal; he promises an exact analysis of it. This is of a yellow colour, and mixed with clay.

The green lead ore, discovered by Gahn, consists of lead mineralised by the acid of phosphorus. It may be analysed in the humid way, by the process mentioned under the article LEAD. If urged by the blow-pipe, it melts, and affords an opake globule without reduction, which in cooling assumes a polyhedral form, whose facets, though apparently plain, are in fact composed of concentric striæ, when observed by the microscope.

The red lead spar or ore consists of lead mineralised by arsenic, and has not hitherto been found elsewhere than at Catherineburgh, in Siberia. Externally it is of a pale, and internally of a deep red colour, and for the most part crystallized in rhomboidal parallelopipeds, or irregular pyramids. According to Lehman, it contains sulphur, arsenic, and about 34 per cent. of lead, and also silver, according to Pallas. Mongez mentions a lead ore of a greenish yellow colour, in a matrix of quartz, coming likewise, as he was informed, from Siberia, of which he found the mineralizer to be arsenic.



The calciform lead ores contain fixed air, which is considered as the mineralizer. They effervesce with acids, and are easily reduced on the charcoal. Kirwan distinguishes five varieties. 1. White lead spar, lead ochre, or native ceruss. It is sometimes transparent, but generally opaque, and crystallized in regular forms, of a laminar or striated texture. Lead ochre, or native ceruss, is the same substance, but in a loose form, or indurated and shapeless; sometimes it is found in a silky form. Both contain a little iron, and sometimes calcareous earth and argill. Both grow red hot or yellowish when sufficiently heated. They effervesce with acids, and afford from 60 to 80 or 90 per cent. of lead; both are found in Brittany, Lorain, Germany, and England. 2. Red, brown, or yellow. This is also found either regularly crystallized, or in shapeless masses, or in powder. It differs from the former only by containing more iron. That in powder contains a mixture of clay. It affords about 70 or 80 per cent. of lead. 3. Green. Either crystallized in needles as in Brittany, or in a loose powder as in Saxony, but mostly adhering to, or investing quartz. It owes its colour to iron, and seldom contains copper. 4. Blueish. This is also sometimes crystallized, sometimes irregular. 5. Black. The most uncommon of all, and occurs either crystallized, or of an indeterminate form.

Lead mineralized by sulphur is the commonest of all lead ores. It is known by the name of galena, or potter's lead ore, and is of a blueish dark lead colour, formed of cubes of a moderate size, or in grains of a cubic figure whose corners have been cut off; its texture is lamellar, and its hardness variable; the hardest sort containing a greater mixture of iron or quartz; that in grains is thought to be the richest in silver; but the richest contains only about one or 1,5 per cent. that is, 12 or 18 ounces per quintal, the poorest about 60 gr. Ores that yield about half an ounce of silver per quintal are barely worth the cost of extracting them: the proportion of sulphur to lead in this ore is also variable within the limits of 15 and 25 per cent. that which contains least is called bley schweif, and is in some degree malleable. The proportion of lead is from 85 to 60 per cent. by reason of an accidental mixture of quartz; that of iron is generally very small. Dr. Watson remarks, that the ores which are poorest in lead are often the richest in silver. The specific gravity of galena is from 7,000 to 7,780; when melted it yields a yellow slag.

The antimonial lead ore has the same colour and weight as galena, but its structure is commonly radiated like that of the ore of antimony. Besides the more accurate methods of humid solution, the antimony may be easily perceived, though in small quantities, by the white and abundant fumes it emits in roasting.

In the smelting of ores of lead they may be considered either as pure, that is, containing no mixture of other metals, or they are mixed with silver, copper, or pyrites. The methods of treating ores of lead containing silver and copper, are described in the articles ORES of SILVER and of COPPER, which see.

Pure ores of lead, and those which contain so small a quantity only of silver as not to compensate for the expence of extracting the nobler metal, may be smelted in furnaces, and by operations similar to those used at Rammelsberg, or by the following methods:

1. From the lead-ore of Willach in Carinthia, a great part of the lead is obtained by a kind of eliquation, during the roasting of the ore. For this purpose, the ore is thrown upon several strata or layers of wood, placed in a calcining or reverberatory furnace. By kindling this wood, a great part of the lead flows

out

out of the ore, through the layers of fuel, into a basin placed for its reception. The ore which is thus roasted is beat into smaller pieces, and exposed to a second operation similar to the former, by which more metal is eliquated; and the remaining ore is afterwards ground, washed, and smelted in the ordinary method.

The lead of Willach is the purest of any known. Schlutter ascribes its great purity to the method used in extracting it, by which the most fusible, and consequently the purest part of the contained lead is separated from any less fusible metal which happens to be mixed with it, and which remains in the roasted ore. This method requires a very large quantity of wood.

2. In England, lead-ores are smelted either upon a hearth, or in a reverberatory furnace, called a cupel.

In the first of these methods, charcoal is employed as fuel, and the fire is excited by bellows. Small quantities of fuel and of ore are thrown alternately and frequently upon the hearth. The fusion is very speedily effected; and the lead flows from the hearth as fast as it is separated from the ore.

3. In the second method practised in England, pit-coal is used as fuel. The ore is melted by means of the flame passing over its surface; its sulphur is burnt and dissipated, while the metal is separated from the scoria, and collected at the bottom of the furnace. When the ore is well cleansed and pure, no addition is requisite; but when it is mixed with calcareous or earthy matrix, a kind of fluor or fusible spar found in the mines is generally added, to render the scoria more fluid, and thereby to assist the preparation of the metal. When the fusion has continued about eight hours, a passage in the side of the furnace is opened, through which the liquid lead flows into an iron cistern. But immediately before the lead is allowed to flow out of the furnace, the workmen throw upon the liquid mass a quantity of flaked quick-lime, which renders the scoria so thick and tenacious, that it may be drawn out of the furnace by rakes. Schlutter mentions this addition of quick-lime in the smelting of lead-ores in England, but thinks that it is intended to facilitate the fusion of the ores; whereas it really has a contrary effect, and is never added till near the end of the operation, when the scoria is to be raked from the surface of the metal.

**ORES OF MANGANESE.** From the extreme disposition of manganese to become calcined, it is hardly to be expected that a native regulus should be found. But Mr. Peyrouse describes a substance of this kind in the *Journal de Physique* for 1786, which appears to be native manganese, from the following properties extracted by Magellan \*. 1. Its external appearance, colour and figure are the very same as those of the artificial regulus of manganese. 2. It likewise soils the fingers when handled. 3. Its substance is quite pure, having no particles that are in the least attracted by the magnet. 4. Its texture is lamellated, and the lamellæ seem to affect a kind of divergence among themselves. 5. It has the very same metallic brilliancy as the artificial manganese. 6. It has also a partial malleability: and, when repeatedly hammered, 7. It exhibits a kind of exfoliation, forming itself into very thin leaves. 8. Its opacity and density are so completely similar to that of the artificial regulus, that, were it not for the natural matrix in which it is imbedded, it could not be at all distinguished from it. 9. This ore is not found in large masses, or in a solid continued body, but only in lumps, and unconnected clots, inclosed and intermixed

\* Cronstedt, ii. 853.



with the powdery manganese ore. 10. These lumps are somewhat flattened, or compressed in their figure, like the artificial ores, though they are for the most part of a larger size. 11. And this powdery manganese ore, in which the reguline lumps are imbedded, has an argentine hue, which seems to countenance the suspicion of its having been acted upon by the violent heat of some natural deflagration on the spot.

This new manganese ore was found among the iron mines of Sem, on the valley called Viederfos, in the county of Foix, near the Pyrenean mountains.

Fixed air is the only mineralizer of manganese in a dry state, yet known. The colours of the compound are different according to the state of calcination of the metallic substance. For, as Scheele has ascertained, manganese is white when as near the metallic state as possible without being actually reduced. This white calx contains about 40 per cent. of fixed air, which prevents its further reduction by exposure to the atmosphere. In proportion to its calcination, and by union with other substances, its colour is either blue, green, yellow, red, brown, or black. It is blue when united with fixed alkalis; yellow always arises from the prevalence of the calx of iron; red, from a slight calcination of the manganese; and black, from its thorough calcination. Yet if the black calx be long roasted, it becomes green, which Kirwan thinks arises from the expulsion of fixed air, which leaves its phlogiston with the manganese, and thus produces a blue, and by mixture with the yellow calx of iron, a green. This author, who has since rejected the doctrine of phlogiston, would probably modify his explanation by substituting charcoal or the basis of fixed air instead of that principle. The brown colour of manganese arises from a mixture of the red and black calces. Hence Kirwan distinguishes three principal varieties of the native calx of manganese, the white, the red, and the black, the account of which I shall here extract from his Mineralogy.

**VARIETY I.** White ore of manganese. This contains but a very small proportion of iron; it has been found by Mr. Rinman both in small white crystals, and in round masses, in the cavities of quartz and adhering to glanzblend, rather less hard than lime-stone, of a sparry texture, and scarcely magnetic, even after roasting, soluble with effervescence in nitrous acid, and affording a colourless solution; which solution, with mild alkalis, gave a white precipitate, and the precipitate, when heated, presently grew black; a sure criterion of manganese.

Mr. Lapeirouse found this white ore in the form of a spungy efflorescence, vegetating on the surface of some iron ones, particularly hematites.

It has been seen also by Mr. Rinman in the form of a calcareous spar, of the colour of rosin, and somewhat shining, in some places covered over with a sooty powder, and in thin pieces semi-transparent at the edges, and not hard enough to strike fire with steel; nitrous acid dissolves it almost entirely; with mild alkalis, the solution gives a white precipitate, which blackens when heated. It consists of manganese embodied in zeolyte; it melts per se with the blow-pipe into a whitish gray porous slag, and with the addition of calcined borax gives a garnet-coloured glass.

Many of white sparry iron ores may also be classed among the ores of manganese, as they contain more of it than of iron.

**VARIETY II.** Red ore of manganese. It contains less fixed air, and is accompanied with more iron than the former variety, and also with calcareous or ponderous earth and filix. It is found either loose and semi-indurated in a matrix of calcareous spar, or talky schistus, or on hematites and other iron ores, or in heavy hard

hard masses of a lamellar, radiated, or equable texture, or crystallized in pyramids, rhomboids, or short bright brittle needles.

VARIETY III. Black and brown ore of manganese. Kirwan places these together, as they differ but little; they are found either crystallized in the same form as the red ore, or in solid masses, some of which have a metallic appearance; others are dull, earthy, and mixed or embodied with quartz, or in a loose earthy form; their specific gravity is about 4,000. Both, particularly the brown and the red, are soluble in some measure by digestion in oil of vitriol, and the solution is at first reddish, but afterwards becomes colourless, unless they contain a large proportion of iron. But the dephlogisticated nitrous acid does not act on them except sugar be added; and then this acid, as well as the concentrated vitriolic, operates a colourless solution, which with mild alkalis gives a white precipitate of the same nature as the first variety: they contain more iron and less fixed air than the former varieties.

Perigor stone belongs to this variety: it is of a dark gray colour, like basalt or trapp, may be scraped with a knife, yet is difficultly broken; when calcined it becomes of a reddish brown colour, and harder, but not magnetic. Its specific gravity is considerable; it does not melt per se, but with borax it affords an amethystine glass; nitrous acid scarcely acts on it without the addition of sugar. This stone seems also to contain clay, and some portion of iron.

One of the most remarkable ores of manganese is that called black wad; it is of a dark brown colour, partly in powder, and partly indurated, and brittle. If half a pound of this be dried before a fire, and afterwards suffered to cool for about an hour, and then two ounces of lint-seed oil be gradually poured on it, mixing them loosely like barm with flour, little clots will be formed, and in something more than half an hour the whole will gradually grow hot, and at last burst into a flame. The temperature of the room where the experiment was made, Mr. Kirwan being present, was about 50. : the heat this ore was exposed to while drying might be about 130.

According to Wedgwood's analysis, 100 parts of black wad contain 43 of manganese, 43 of iron, 4.5 of lead, and five of mica.

To analyse the above-mentioned ores, they should be first roasted to calcine effectually the manganese, and iron if any; then treated with pale nitrous acid to dissolve the earths; the residuum should then be treated with nitrous acid and sugar, by which means a colourless solution of manganese will be obtained; and this being precipitated by aerated mineral alkali will give a precipitate, 100 gr. of which are equivalent to 100 of regulus of manganese.

Many species of iron ore contain manganese. To discover it, let the iron be dissolved in some acid, and precipitated by the Prussian alkali; let the solution be poured off, and the precipitate digested in pure water; the Prussian manganese will be dissolved, and the Prussian iron remain undissolved.

Manganese seems to be contained in the ashes of most vegetables, and to it the blue or greenish colour of calcined vegetable alkali is owing. These colours are generally attributed to the phlogiston of the alkali; but if so, they should not be found in fixed nitre, as the nitrous acid should carry off during its decomposition all the phlogiston; yet this alkali is always greenish, so that the colour seems to arise from the ashes of the charcoal with which the nitre was decomposed. If three parts of the alkali of tartar, one of sifted ashes, and one-eighth of nitre be melted together, they form a dark green mass, which being dissolved in water affords a beautiful green solution; and this being filtered, on the addition of a few drops



of oil of vitriol, becomes red, and after a few days a brown powder is deposited, which has the properties of manganese. The ashes of serpyllum contain very little of it, those of trees contain most. Scheele.

**ORES OF MERCURY.** Mercury is found in a native state sufficiently distinguishable from every other metallic substance, by its fluidity in every ordinary temperature of the habitable parts of the globe. Bergman doubts whether it be ever found uncontaminated by any other metal. It is found in the quicksilver mines in small brilliant globules, disseminated in different gangues. Mongez asserts, that it is mostly in a state of great purity. Sometimes it is collected in the cavities of rocks, as at Idria in Spain, and in America; and in other instances it is disseminated in the earth, in clays, or adherent to quartzose stones, pot-stone mica, or else mixed with different ores, as the white or red silver ores, galena, white arsenic, or cinnabar.

Mercury has been found in Sweden and elsewhere, united to silver in the form of an amalgam sometimes crystallized.

M. Sage, in the *Journal de Physique* for 1784, mentions a calciform ore of mercury of a red-brown colour, difficult of fracture, presenting a granulated texture more red than externally. It frequently contains running mercury in its interstices. By distillation the mercury is obtained in the proportion of 91 parts in the centenary. It contains a small part of silver, and comes from Idria.

Mercury was found by M. Woulfe at Obermoschel in the Duchy of Deux-ponts, united with the marine and vitriolic acids. These ores have a spar-like appearance, and are either bright and white, or yellow or black mixed with cinnabar in a stony matrix. The marine salt was in the state of corrosive sublimate.

The ore of mercury which is wrought in the large way is CINNABAR. It is a combination of mercury with one-fourth of its weight of sulphur. See the article.

There are other impure cinnabars, particularly one containing copper, which is of a blackish gray colour, glassy texture, and decrepitates strongly when heated. The cinnabar may be volatilized by heat, and the remaining copper shews itself by the usual tests. The ore of mercury containing iron, and distinguished by the name of pyritous mercurial ore, is a gray or whitish friable substance found in Dauphiny, and afforded M. Monnet one part of mercury, less than half a part silver, and the rest was iron, cobalt, arsenic, and silver.

#### PROCESS I.

(Cramer, process 8.)

*To separate mercury out of an unsulphureous ore by distillation.*

Take a lump of the pulverised ore, one common pound, which must stand for one centner: put it into a glass retort perfectly clean, well loricated, or coated up to half the length of its neck: this must be very long, and turned backwards with such a declivity, that a glass recipient may be perpendicularly applied to it: but you must choose a retort small enough, that the belly of it may be filled hardly two thirds with the ore: this retort must be placed so, that nothing of the fluid adherent to the neck of it may fall into the cavity of the belly, but that the whole may run forward into the recipient. Lastly, take a small recipient full of cold water: let it be perpendicularly situated, and receive the neck of the retort in such a manner that the extremity of it may be hardly one half inch immersed into the water.

Let the retort be surrounded with hot burning coals placed at some distance in the

the form of a circle, lest the vessel should burst by too sudden a heat: then by degrees bring the burning coals nearer and nearer, and at last surround the whole retort with them and with fresh charcoal, that it may grow slightly red-hot: this fire having been continued for an hour, let the retort cool of itself: then strike the neck of it gently, that the large drops which are always adherent to it may fall into the recipient: let the recipient be taken away, and the water separated from the mercury by filtration, and let the mercury be weighed. This operation may be more conveniently performed in a sand bath; in which case the pot containing the sand must be middling red-hot, and the retort be able to touch the bottom of it immediately; nor is it then necessary that the retort be loricated.

## PROCESS II.

(Cramer, process 59.)

*To revive mercury from a sulphureous cinnabar ore.*

Beat your ore extremely fine, and mix it exactly with an equal portion of iron filings, not rusty; and proceed to distil it with the same apparatus as in the former process; but urge it with the strongest fire that can be made.

Cinnabar may be separated from stones by sublimation as follows: Beat it to a fine powder, and put it into a small, narrow glass or earthen cucurbit, the belly of which must not fill more than one third part: stop the orifice at top; this must be very narrow, to hinder the free action of the air. Put this small cucurbit in an earthen pot above two inches wide in diameter, and gather sand around this pot about as high as the pulverized ore rises in the cucurbit. Then put it upon burning coals in such a manner that the bottom of the pot may be moderately red-hot. Thus will your cinnabar ascend, and form a solid ponderous ring, which must be taken out by breaking the vessel.

**ORES OF MOLYBDENA.** See ACID OF MOLYBDENA, also MOLYBDENA.

**ORES OF NICKEL.** This semi-metal has been found by Rinman in a cobalt mine in Hesse. The mineral is very ponderous, and of a livid colour. When pulverized and roasted under a muffle it forms a green excrescence, and smokes; but its smoke has no peculiar smell, and no sublimate whether sulphureous or arsenical can be caught. It affords a green solution with acids; but a polished iron plate discovers no indication of copper.

Nickel is also found in the calciform state, afforded by the decomposition of kupfer nickel. It usually has the form of a green efflorescence, and often covers the ores which contain it. Cronstedt informs us that it is found at Normark in Warmeland, without any appearance of kupfer nickel, in a clay which contained much native silver.

The ore long distinguished by the name of kupfer nickel, before the discovery of the peculiar metal by Cronstedt, is of a reddish-yellow colour, and of the texture and appearance of a slag, or else of a fine granular texture, or lastly, of a scaly or lamellar texture. Its brilliancy in some measure resembles that of the common pyrites. This ore contains nickel, with iron, cobalt, and arsenic mineralized with sulphur. See NICKEL.

**ORES OF PLATINA.** This comes to us in an impure native state. Its ores if any are unknown. See PLATINA.

**ORES OF SILVER.** The great value of this metal has occasioned its ores to be very particularly attended to, and enumerated. In the present article I shall chiefly follow the arrangement of Kirwan.

Native silver is found in a granular, lamellar, filamentous, capillary, arborescent,



cent, or crystallized form, inhering either in baroselenite, lime-stone, selenite, quartz, chert, flint, serpentine, gneiss, agate, mica, calcareous spar, pyrites, schistus, clay, &c. also in separate masses of various sizes, some of the weight of 60 pounds, in or near the veins of most metallic substances, particularly in Peru, and frequently in various parts of Europe, either of a white, brown, or yellowish colour.

It is often diffused through sand and ochre, also in gray lime-stone in Lower Austria, and in a greenish clay near Schemnitz, or mixed with ochre, clay, and calciform nickel.

It is seldom found pure, being generally alloyed with copper, and sometimes with a small proportion of gold, iron, or regulus of antimony, and sometimes about five per cent. of arsenic; it is separable from gold and regulus of antimony by solution in nitrous acid, and from copper and iron by precipitating it by the marine acid, and from arsenic by torrefaction. Cronstedt says its purity is generally approaching to 16 carats. Lewis asserts that it never exceeds this fineness. The native silver found near Kongberg contains so much gold as to acquire a yellow colour from it.

Horn-silver, or corneous silver ore, is of a whitish-gray or dirty yellow colour, sometimes semi-transparent, easily cut with a knife, fusible even by the flame of a candle, and assuming a violet colour by the sun's rays. One hundred grains contain 75 of real silver. It is reducible by triturating it with about its own weight of fixed alkali with a little water, then melting the whole in a crucible, whose bottom is covered with mineral alkali well pressed, and covering the mass of horn-silver also with the mineral alkali.

The vitreous silver ore (glaszertz) is mineralized by sulphur. It is found either in solid large lumps, or inhering in quartz, spar, gypsum, gneiss, pyrites, &c. of a lamellar, granular or capillary form crystallized: it is generally of a lead colour first, but grows black by exposure to the air, but sometimes gray or black, even when first broken; its laminæ are flexible and ductile, and even malleable in some degree, and so soft, that they may be cut with a knife; its specific gravity is 7.200\*; it is one of the richest of the silver ores.

One hundred parts of it contain from 72 to 77 of silver; it is rarely contaminated with any other metal besides a small proportion of iron.

It is found in Hungary near Schemnitz, and in Saxony near Freyburgh, particularly in the famous mine of Himmelsfurst.

It is analysed by boiling in moderately dilute nitrous acid, using about 25 times its weight, till the sulphur is quite exhausted. The silver is precipitated by marine acid, or common salt. The Prussian alkali will shew if any other metal is contained in the solution: the gold, if any, will remain undissolved; fixed alkalis will precipitate any other earthy matters contained in the solution.

In the dry way it may be reduced by melting it with the blow-pipe on charcoal; for the sulphur is dissipated, and the silver remains; or by melting it with  $\frac{1}{4}$  of its weight of filings of iron, as the iron will take up the sulphur, and be scorified.

Silver is either mineralized by a small or a large proportion of arsenic. The ore which is mineralized by a small proportion of arsenic, is of a yellowish-white colour, and of a striated texture, resembling bismuth, but much harder; it melts very easily; and if kept in fusion, it loses its arsenic, and the silver remains al-

\* Gellert Anfangs, 234.

most entirely pure, as it contains but very little iron; it contains about 90 per cent. of silver, and is found near Quadanal Canal in Spain.

The proportion of arsenic in that silver ore which is mineralized by a large proportion of it, is so great, that it would scarce deserve to be called a silver ore, if the arsenic were not easily dissipated: the quintal contains but from four to six ounces of silver! it is very soft, and easily cut, and when cut has a brilliant metallic appearance; it consists of conchoidal laminae; it is also found at Quadanal Canal.

It is reduced by evaporating the arsenic, which then leaves the silver slightly contaminated with iron.

The red silver ore is mineralized by sulphur and arsenic (rothgulden ertz). This is a heavy, shining substance, either transparent or opaque, mostly of a crimson or reddish colour, though sometimes gray or blackish, but when scraped or powdered always reddish; found either in irregular masses, or crystallized in pyramids or polygons, or dendritical, or plated or radiated incrustations, on or in matrixes of quartz, flint, spar, pyrites, sparry iron ore, lead ore, pyrites, cobalt ore, jasper, barofelenite, gneiss, &c. When radiated or striated, it is called rothgulden bluth. In the fire it crackles and melts after it has acquired a red heat, with an arsenical smell; it detonates with nitre: its specific gravity is from 5.4 to 5.684. Bergman found 100 grains of it to contain 60 of silver, 27 of arsenic, and 13 of sulphur; but sometimes it contains even 70 per cent. of silver. The darkest ores are the richest, and these often contain a little iron; the yellowest are the poorest; the most yellow does not belong to this species, being in fact orpiment, containing six or seven per cent. of silver.

To analyse this ore in the moist way, Bergman advises to boil it after it is reduced to a very fine powder in dilute nitrous acids, and to edulcorate the residuum very carefully which contains the sulphur and arsenic, which may be separated by boiling in a sufficient quantity of aqua regia: if the sulphur still retains any luna cornea, it may be separated by caustic volatile alkali.

In the dry way it is reduced after torrefaction by a mixture of iron and lead; the iron takes up the sulphur, and the lead the silver, which is afterwards separated by cupellation.

Silver mineralized by sulphur, and a very small portion of arsenic and iron, is called black silver ore, schwarz ertz, schwarz gulden, silber malm. This is either of a solid and brittle consistence, which distinguishes it from the vitreous ore, and of a glassy appearance in its fracture when recent, or of a looser texture, and sooty or deep black colour, like moss or thin leaves lying on the surface of other silver ores, or of those of lead or cobalt, or in clays, ponderous spar, gneiss, &c. It may contain about 25 per cent. of silver: the former is found in Dauphiné, Hungary, and Saxony, and contains at most 60 per cent. of silver.

Another species of silver ore mineralized by arsenic, and containing a large proportion of iron, is called arsenico-martial silver ore, weiss ertz, pyrites argenteus of Henckel.

Mineralogists do not well agree about the ore to which this denomination belongs. Kirwan follows Monnet, who seems to have attended most exactly to the division of ores. According to him, this ore is a hard substance, of a white, shining appearance, and of a compact, lamellar or fibrous texture; the brightest is the poorest in silver; the richest gives only 10 per cent. the poorest six or eight ounces: it contains no sulphur; and hence Monnet calls it a metallic regulus, not



considering that the iron is in a calcined state: the iron and arsenic are in various proportions, but the arsenic always exceeds.

It is found in Saxony, the Hartz, at Quadanal Canal, &c. and is assayed in the moist way.

White silver ore (weis gulden) is mineralized by arsenic and sulphur, with a small proportion of copper, and a still smaller of iron. It is a heavy, soft, opaque substance, fine grained or scaly, bright and shining in its fractures, of a whitish, steely or lead colour, sometimes crystallized in pyramidal or cylindrical forms, but often in irregular grains, or resembling moss, or in the form of thin laminæ incrustating other bodies, found in quartz, spar, stellerstein, pyrites, blend, lead ore, cobalt ore, sparry iron ore, fluors, &c. It is very fusible; its specific gravity 5,000 to 5,300; its proportion of silver from 10 to 30 per cent.

It is found, though not commonly, in Saxony, Hungary, the Hartz, and St. Marie aux Mines.

Bergman analyses this ore in the following manner: Having pulverized and weighed a certain portion of it, he attempts its solution in about 12 times its weight of dilute nitrous acid: the copper and silver are dissolved, and a white residuum remains. The silver he precipitates, not with marine acid, for this would unite also to the copper, and with the silver form a triple salt, which would also fall, but with a clean plate of copper previously weighed; the silver being in its metallic form, may immediately be weighed, and its contents known: the copper should then be precipitated by aerated mineral alkali; 194 grains of this precipitate well dried are equivalent to 100 of copper in its metallic form; but from this last, the weight, which the plate of copper lost, must be subtracted.

The white residuum, containing the sulphur, arsenic and iron, is next to be examined: by boiling it in spirit of salt, the arsenic and iron are taken up; the arsenic is to be precipitated by the addition of water, and then the iron by the Prussian alkali; the sulphur remains undissolved, and may be treated with volatile alkali to try whether it retains any copper or horn silver.

Gray silver ore (fahlerz) is mineralized by arsenic and sulphur, with a large proportion of copper and some iron. This is a hard, gray, or dark gray substance, more or less brilliant, sometimes crystallized, but mostly irregular, and is, in fact, the gray copper ore impregnated with silver, and varies much in its contents from about one to 12 per cent. of silver, and from 12 to 24 of copper, the remainder being sulphur and arsenic, with a little iron: the richer it is in copper, the poorer in silver, and reciprocally. Monnet remarks, that wherever copper is united to arsenic, silver is also found; it is the commonest of all the silver ores: the gray silver ore of Dal in Sweden contains also regulus of antimony, and according to Bergman, it contains 24 per cent. of copper, and five of silver; but this belongs to the next species, which is

Brown silver ore (leber erz), and is mineralized by arsenic and sulphur, with copper, iron, and regulus of antimony. The colour of this ore is mostly of a reddish brown, sometimes dark gray; sometimes it is found crystallized in pyramids, but mostly irregular; when scraped it appears red; it contains from one to five per cent. of silver; the greatest part is copper, and the next in proportion is arsenic.

It is found in Sweden, Germany, and Spain.

It

It is analysed by boiling it in about six times its weight of dilute nitrous acid, which will take up the silver and copper, and leave the regulus of antimony and arsenic: these being boiled in strong nitrous acid are dephlogisticated, and the arsenic becomes soluble in water; the calx of antimony remains undissolved; the sulphur may be found in a second experiment, using aqua regia instead of the concentrated nitrous acid; the silver and copper are separated, as in the process for the white silver ore.

Plumose silver ore (*feder ertz*) is mineralized by sulphur and arsenic, with iron and regulus of antimony. In point of colour this ore varies from a dull white to gray, dark blue, brown or black; it is found in a capillary form, or like wool, sometimes loose, at other times attached; its filaments are rigid and inflexible; the whiter it is, the richer; but it seldom contains even one per cent. of silver. It is found in Saxony and elsewhere. Some confound it with the foregoing.

Its analysis may be understood from the processes with the white and brown silver ores.

Cobaltic silver ore is mineralized by sulphur and arsenic, with cobalt and iron. This ore is distinguished by rose-coloured particles of cobalt dispersed through a dark brown, blackish, or gray, and somewhat shining solid mass. It is found in Saxony, and at Allemont in Dauphiné, and contains about 40 or 50 per cent. of silver, and very little cobalt; the arsenic is in an acid state, and united to the cobalt.

To analyse it, let it be dissolved in nitrous acid; the silver and cobalt will be taken up, and most of the iron will remain calcined, together with the arsenic; the silver may be precipitated by the marine acid, and the cobalt by mild mineral alkali: 160 grs. of the precipitate denote 100 of cobalt in its metallic state.

Butter-milk ore is mineralized by sulphur, with regulus of antimony and barytes; and appears in the form of thin pellicles on granular spar.

The combustible silver ore is black and brittle, leaves about six per cent. of silver in its ashes, and is a coal in which silver is found. The silver is extracted as usual by nitrous acid.

Corneous silver ore (*horn ertz*) is mineralized by the vitriolic and marine acids, with a little iron, and sometimes with a mixture of the vitreous ore. This scarce and valuable ore is of a white, gray, pearly, or yellow, green, brown, purple, or black colour, frequently crystallized in a cubic form, sometimes resembling an earth, easily fusible without any smoke. The black sort is friable, and easily pulverised; but the other sort is in some degree malleable, may be cut with a knife, and takes a sort of polish when rubbed. The vitreous ore mixed with the black is soluble in nitrous acid, and may by that means be separated, the saline ores being insoluble in that acid; if pure from iron, these ores should contain 70 per cent. of silver at least, but they mostly contain some portion of iron, of which some is even united to the marine acid, according to Monnet. It is found in Saxony, Bohemia, St. Marie aux Mines, Siberia, and Peru. It was first assayed by Wolfe, *Phil. Trans.* 1776, and afterwards, though less exactly, by Monnet, in 1777.

Bergman gives the following most ingenious method of analysing these ores in the moist way.

1°. He digests this compound ore in the marine acid for 24 hours, by which means the vitriol of silver is decomposed, and the whole is converted into horn silver. He then judges of the quantity of the vitriol of silver, by the quantity of vitriolic acid let loose in the liquor; and to find how much this is, he decants



the clear liquor, and drops into it a solution of nitrous baroselenite, which is immediately decomposed by the vitriolic acid, and forms true vitriolic baroselenite, of which 100 grains contain 15 of dephlegmated vitriolic acid; and so in proportion. Now 100 grains of vitriol of silver contain 25,37 of the same dephlegmated acid, so that 25,37 grains of this acid indicate 100 of vitriol of silver, and so in proportion; and thus the quantity of silver in the vitriol of silver is also found, as 100 grains of it contain 74,62 of silver\*, and the proportion of vitriol of silver being known, that of horn silver of course is known; but if the ore be of the black kind, after the whole is turned into horn silver, it should be digested in caustic volatile alkali, which will take up the horn silver, and leave the vitreous ore. The iron, if any, should be precipitated from the first solution, by the Prussian alkali, after the precipitation of the baroselenite.

*The following processes, like the others extracted from Cramer's Art of Assaying, are valuable for the minute accuracy of the instruction as to management of assays by the furnace.*

#### PROCESS I.

*To precipitate silver by means of lead from fusible ores.*

Pound the ore in a very clean iron mortar into fine powder: of this weigh one docimastical centner or quintal, and eight of the like centners of granulated lead.

Then have at hand the docimastical test, which must not as yet have served to any operation: pour into it about half of the granulated lead, and spread it with your finger through the cavity of it.

Put upon this lead the pounded ore; and then cover it quite with the remainder of the granulated lead.

Put the test, thus loaded, under the muffle of an essay-furnace, and in the hinder part of it: then make your fire, and increase it gradually. If you look through the holes of either of the slides, you will soon see that the pounded ore will be raised out of the melted lead, and swim upon it. A little afterwards, it will grow clammy, melt, and be thrown towards the border of the test: then the surface of the lead will appear in the middle of the test like a bright disk, and you will see it smoke and boil: as soon as you see this, it will be proper to diminish the fire a small matter for a quarter of an hour, so that the boiling of the lead may almost cease. Then again increase the fire to such a degree that the whole mass may be converted into a thin fluid, and the lead may be seen, as before, smoking and boiling with great violence. The surface will then diminish by degrees, and become covered with a mass of scorias. Finally, have at hand an iron hook ready heated, wherewith the whole mass must be stirred, especially towards the border; that in case any small parcels of the ore, not yet dissolved, should be adherent there, they may be brought down, taking great care not to stir the least particle out of the test.

Now, if what is adherent to the hook during the stirring, when you raise it above the test, melts quickly again, and the extremity of the hook, grown cold, is covered with a thin, smooth, shining crust; it is a sign that the scorification is perfect; and it will be the more so, as the said crust adherent to the hook shall be coloured equally on every side; but in case, while the scorias are stirred, you perceive any considerable clamminess in them, and when they adhere in good quan-

\* According to Bergman, 100 parts of vitriol of silver contain but 68,75 of silver.

nity to the hook, though red-hot, and are unequally tinged, and seem dusty or rough with grains interspersed here and there; it is a sign that the ore is not entirely vitrified. In this case, you must with a hammer strike off what is adherent to the hook, pulverize it, and with a ladle put it again into the test, without any loss or mixture of any foreign body, and continue the fire in the same degree till the scoria has acquired its perfection, and the above-mentioned qualities. This once obtained, take the test with a pair of tongs out of the fire, and pour the lead, together with the scoria swimming upon it, into a cone made hot and rubbed with tallow. Thus will the process of the first operation be performed, which does not commonly, indeed, last above three quarters of an hour.

With a hammer strike the scorias off from the regulus grown cold, and again examine whether they have the characteristics of a perfect scorification: if they have, you may thence conclude, that the silver has been precipitated out of the ore turned to scorias, and received by the lead.

When the scorification lasts longer than we mentioned, the lead at last turns to scorias or litharge, and the silver remains at the bottom of the vessel; but the fire must be moderately supplied, and the vessel be extremely good, to produce this effect; for they seldom resist the strength of the scorias long enough; so that the whole scorification may be brought to an end; which has afterwards this inconvenience, that the silver is dissipated by grains in the small hollows of the corroded ore, and can hardly be well collected again, when the ore has but little silver in it. Indeed, there is still more time to be consumed to obtain the perfect destruction of the lead, by means of the combined actions of the fire and air, because the scorias swimming at the top retard it considerably.

In this process, the sulphur and the arsenic of the silver ore, when the ore is broken small, and extended widely in a small quantity, are in part easily dissipated by the fire, and in part absorbed by the lead; the lighter part of which, swimming upon the heavier, becomes very clammy by means of the sulphur which is in the ore; but when this is dissipated by the violence of fire, it turns into glass or scorias: but when arsenic is predominant in the ore, the plumbeous part turns immediately into a very penetrating and very fusible glass, having a dissolving efficacy, unless the arsenic lies hidden in a white pyrite or cobalt. For this reason, the fixed part of the ore, which is no silver, is dissolved by that glass, melts, and assumes the form of scorias. The unmetallic earths and the pure copper or lead-ores which adhere to it are of this kind. The silver then remains immutable; and being freed from these heterogeneous bodies, which are partly dissipated and partly melted, it is precipitated and received by the remaining regulus of lead. Hence this process is completed by three distinct operations; viz: 1. By roasting. 2. By scorification. 3. By the melting precipitation of the silver, which is the result of the two former operations.

The ore must be pulverized very fine in order to increase the surface, that the dissipation of the volatiles, and the dissolution by litharge, may be sooner effected. This pulverising must then be done before the ore is weighed, because there is always some part of the ore adherent to the mortar or iron plate on which it is made fine; which part being lost, the operation is not exact. Erker was in the right when he prescribed eight centners of lead for the subduing of fusible ores. Nevertheless, it must be owned that this quantity is superfluous in some cases. However, as the fluxibility of the silver ore depends on the absence of stones, pyrites, &c. it is easy to see that there are an infinite number of degrees of fluxibility which it would be needless to determine by the



bare sight. Besides, a little more lead does not render the process imperfect; on the contrary, if you use too small a quantity of lead, the scorification is never completely made. Indeed, there are a great many ores containing sulphur and arsenic in abundance, that destroy a considerable quantity of lead: such are the red silver ore, and that in which there is a great deal of the steel-grained lead ore. If the fire must be sometimes diminished in the middle of the process, it is in order to hinder the too much attenuated litharge, which is continually generated out of the lead, from penetrating the pores of the test, and from corroding it; which is easily done when the fire is over strong; for then the surface of the vessel which is contiguous to the lead contracts cavities, or, being totally consumed by small holes, lets the regulus flow out of it. The vessels that are most subject to this inconvenience are those, in the materials of which lime, plaster, and chalk, are mixed. Nay, these bodies, which are naturally refractory, being eroded during their scorification, at the same time communicate a great clamminess to the scoria; so that a great quantity of the mass remains adherent to the test in the form of protuberances, when it is poured out; and by this means a great many grains of the regulus are detained.

## PROCESS II.

The regulus obtained by the preceding process, contains all the silver of the ore, and the unscorified part of the lead. The silver may be afterwards separated from the lead, and obtained pure by cupellation.

## PROCESS III.

(Art of Assaying, Part II. process 3.)

*If the silver ore cannot be washed clean, or if it be rendered refractory by a mixture of unmetallic earths and stones, the scorification of these earthy matters frequently cannot be completed by Process I. Cramer therefore directs that such ores shall be treated in the following manner.*

Bruse the ore into an impalpable powder, by grinding in a mortar; to a doctimastral centner of it add a like quantity of glass of lead, finely pulverised; for the more exactly these two are mixed together, the more easily the scorification afterwards succeeds. Put this mixture, together with twelve centners of lead, into the test, according to Process I.; then put the test under the muffle.

Make first under it a strong fire, till the lead boils very well; when this takes place, diminish the violence of the heat, as was directed in Process I. But keep it thus diminished a little longer: then finally again increase the fire to such a degree, till you perceive the signs of a perfect scorification and fusion. Now this process lasts a little longer than the foregoing, and requires a greater fire towards the end.

It sometimes happens that a very refractory ore cannot be dissolved by litharge, and that a mass, which has the clamminess of pitch, swims upon the regulus and upon the scorias themselves, which are already subdued in part: when this takes place, shut the vents of the furnace to diminish the fire; then gently touch this refractory body with a small cold iron hook, to which it will immediately stick; take it off softly, not to lose any thing; pound it into a fine powder, adding a little glass of lead, and put it again into the test; then continue the scorification, till it is brought to its perfection. But you must always examine the scoria of your refractory ore, to see whether there may not be some grains of regulus dispersed in it; for sometimes the scorias that grow clammy retain something of the metal; which if you suspect, pound the scoria into a fine dust, and thus the

grains of metal will appear, if there are any left, because they can never be pounded fine. The silver is separated from the regulus by copelling, as in Process I.

All earths and stones are refractory in the fire; for, although some of them melt naturally in the fire, as is the case with those that are vitrifiable; yet all the others, a very few excepted, melt with much greater difficulty than metals, and never become so thin in the fusion as is requisite for the sufficient precipitation of a precious metal. But litharge itself does not conveniently dissolve these refractory matters by the help of fire alone, unless some mechanical mixture is added to them; for the very moment the said litharge penetrates through the interstices of the refractory ore, and begins to dissolve it, a tenacious mass is produced, which hardly admits any farther dilution by the litharge. You may plainly perceive it, if you make coloured glasses with metallic calces; if you pour carelessly upon them a calx that gives a colour, you will never cause them to be equally dyed on every side, even though you should torture them for whole days together in a strong fire. Indeed, glass already made can never be diluted by only pouring salts and litharge upon it. Hence, you must use the artifice of glass-makers, who, in the making of the most perfect glasses, take great care, before they put the species of their ingredients into the fire, to have a mechanical mixture precede, or at least accede, during the fusion itself, which is done here by pounding glass of lead mixed with the ore: but if you think that your glass of lead is not sufficiently fusible, you may add to it litharge, melted first, and then pounded into a fine powder.

As this scorification requires a longer and a greater fire than the foregoing, and as a greater quantity of litharge is besides this requisite to subdue the refractory scoria; it is easy to see why a much greater quantity of lead must be used here than in Process I.; and although less lead is often sufficient, it is nevertheless proper always to use the greatest quantity that can be necessary; lest, for instance, it should be necessary to try so many times the lead alone, to make it evident how much silver the lead, when alone, leaves in the coppel. Nor is there any occasion to fear lest any thing of the silver be taken away by the lead, provided the coppels be good, and the coppelling duly put in execution: for you can hardly collect a ponderable quantity of silver out of the collected fume of the lead, which rises during the coppelling, as well as out of the litharge, that is withdrawn into the coppel.

#### PROCESS IV.

(Art of Assaying, Part II. process 4.)

*If the ore be rendered refractory by pyrites, Cramer directs that the silver should be precipitated by lead in the following manner.*

Break your ore into a rough powder, and put a centner of it into the test: put upon this another test in the manner of a tile; put it under the muffle hardly red-hot: increase the fire by degrees. There will always be a crackling; which being ended, take away the upper test; for when the vessels have been red-hot about one minute, the ore ceases to split. Leave the ore under the muffle till the arsenic and the sulphur are for the most part evaporated; which you will know from the cessation of the visible smoke, of the smell of garlic, or the acid; then take away the test, and leave it in a place not too cold, that it may cool of itself.

Pour out, without any dissipation, the roasted ore, and with a knife take away what is adherent to the vessel; pound it to a most subtle powder, and grind it together with an equal weight of glass of lead; and lastly, scorify the whole collected.



collected ore in the same test in which the testing was made, unless it has contracted chinks, as was described in Process III.

*Remarks.* Yellow pyrites-ores contain a very great quantity of sulphur, even greater than is necessary to saturate the metal that lies concealed in them. For which reason this superfluous sulphur dissipates in a middling fire; but if it had been mixed with lead it would have rendered it refractory, nor could it afterwards be dissipated from it without a considerable destruction of the lead. The white arsenical pyrites turn also a great quantity of lead into glass, on account of the abundance of the arsenic they contain. In consequence of this, these ores must be previously roasted, that the sulphur and arsenic may be dissipated. Nor is there any occasion to fear lest any part of the silver be carried away with the arsenic; for when arsenic is separated from any fixed body, by a certain degree of fire, it carries nothing of that body away with it.

#### PROCESS V.

(Art of Assaying, Part II. process 9.)

*Silver may be precipitated from its ore by cupellation only, in the following process, given by Cramer.*

Pound one centner of ore, roasted in the manner directed in the last process; beat it to a most subtle powder; and if it melts with difficulty on the fire, grind it together with one centner of litharge, which is not necessary when the ore melts easily; then divide the mixture, or the powder of the ore alone, into five or six parts, and wrap up every one of them severally in such bits of paper as can contain no more than this small portion.

Put a very large coppel under the muffle; roast it well first, and then put into it 16 centners of lead: when the lead begins to smoke and boil, put upon it one of these portions with the small paper it was wrapt up in, and diminish the fire immediately, in the same manner as if you would make a scorification in a test, but in a lesser time. The small paper, which turns presently to ashes, goes off of itself, and does not sensibly increase the mass of the scorias. The ore proceeding from this is cast on the border, and very soon turns to scorias. Increase the fire again immediately, and at the same time put another portion of the ore into the coppel. The same effects will then be produced. Continue your operations in the same manner, till all the portions are thrown in and consumed in the lead. Lastly, destroy the remaining lead with a stronger fire.

The silver that was in the ore and in the lead will remain in the coppel. If you deduct from it the bead proceeding from the lead, you will have the weight of the silver contained in the ore. If the ore employed was easy to be melted, all the scoria vanishes; but if it was refractory or not fusible, all the scoria does not always pass away, but there remains something of it occasionally in the form of dust. A great many ores and metals may be tried this way, except such only as split and corrode the coppels. There are likewise some of them which must be previously prepared, in the same manner as is required to render them fit for going through a scorification. See the preceding PROCESSES.

*Remarks.* The ore thrown at several times upon lead boiling in a coppel, may be dissolved without the foregoing scorification: but this is very far from having an equal success with all kinds of ores; for there are ores and metals which resist very much their dissolution by litharge; and which being on this account thrown on the border, are not sufficiently dissolved; because the litharge soon steals away into the coppel. Nevertheless there are some others which vanish entirely

entirely by this method, except the silver and gold that were contained in them. —A previous roasting is necessary; first, for the reasons mentioned, and then because the ore thrown upon boiling lead should not crackle and leap out; for, having once passed the fire, it bears the most sudden heat.

## PROCESS VI.

(Cramer, process 15.)

*Silver may be precipitated out of the same bodies as were mentioned in the foregoing processes, by scorification in a crucible.*

The body out of which you intend to precipitate silver must be previously prepared for a scorification by pounding and roasting, as mentioned in the former processes. Then in the same manner, and with the same quantity of lead, put it into a crucible strictly examined, that it be entire, solid, not speckled with black spots, like the scoria of iron, especially at its inferior parts, and capable of containing three times as much. Add besides glass-gall and common salt, both very dry, and in sufficient quantities, that, when the whole is melted, the salts may swim at top at the height of about half an inch.

Put the crucible thus loaded into a wind-furnace; shut it close with a tile; put coals round it, but not higher than the upper border of the crucible. Then light them with burning coals, and increase the fire till the whole melts very thin, which will be done by a middling fire, maintained always equal, and never greater; leave it thus for about one quarter of an hour, that the scorification may be perfectly made. Take off the tile, and stir the mass with an iron wire, and a little after pour it out into the mould. When the regulus is cleared from scorias, try it in a test by coppelling it.

*Remarks.* The scorification of any ore whatever, or of any body fetched out of ores, may indeed be made by this apparatus, as well as in a test under a muffle: but it serves chiefly to the end that a greater quantity of metal may be melted from it with profit. For you may put many common pounds of it at one single time into the crucible; but then you need not observe the proportion of lead prescribed in the foregoing process; indeed, a quantity of lead two or three times less is sufficient, according to the different qualities of the object. But the mass will certainly be spilt, unless you choose a very good crucible; for there is no vessel charged with litharge, that can bear a strong fire having a draught of wind, without giving way through it to the litharge.

You add glass-gall and common salt, that they may forward the scorification, by swimming at top; for the refractory scoria rejected by the litharge, and adhering between this and the salts that swim at top, is soon brought to a flux, and the precipitation of the silver is thereby accelerated. They also hinder in a manner a small burning coal fallen into the crucible, from setting the litharge a-boiling, which troubles the operation; for the litharge, or glass of lead, especially that which is made without any addition, as soon as the phlogiston enters into it, rises into a foamy mass, consisting of a multitude of small bubbles very difficult to be confined, unless the phlogiston be entirely consumed, and the litharge reduced to lead, which sometimes rises above the border of the vessel.

Native metallic silver may be separated from the stones and earths with which it is intermixed, by amalgamation with mercury, which operation is to be performed in the same manner as in the separation of native gold.

**ORES OF TIN.** The existence of native tin was long a matter of doubt among mineralogists. It has nevertheless been undoubtedly found in various



places. Magellan\*, among other specimens, mentions, 1. Malleable tin in a granular form, and also foliaceous, bedded in a white hard matter resembling quartz, but which, on proper examination, proved to be arsenic; a circumstance that evinces its being native tin, because the arsenic could not have retained this form if the tin had undergone the fusing heat. It appeared like a thick jagged or scolloped lace or edging, and was found at St. Austel in Cornwall. 2. In the form of crystalline metallic laminæ, or flat crystals, rising side by side out of an edging, which shone like melted tin. They were nearly as thin as the leaves of talc, intersecting each other in various directions, with some cavities between them, within which appeared many specks and granules of tin that could be easily cut with a knife; this also came from Cornwall. 3. In a massy form, more than an inch thick in some places, and inclosed in a stone resembling quartz, which was taken to be a hard crust of crystallized arsenic.

The ores of tin hitherto found are in the calciform state. They are remarkable for their great weight, which is between 5,995 and 6,750, according to Kirwan.

The common ore called tin-stone has a vitrified appearance, resembling a garnet of a blackish-brown colour, but much heavier. Its surface is shining, sometimes striated, and its fracture lamellar; soft enough to be cut or scraped with a knife, and affording a pale red powder. Some authors assert that it contains arsenic, but Kirwan positively denies the existence of arsenic as a mineralizer of tin. The Germans call the irregular compact tin ore by the name of zinn-stein; but the crystallized tin-stones are called zinngrauen, if the crystals are distinct and somewhat large. The zinnzwitter ores, in which the crystals are small and not so distinct, resemble small grains, scattered through a compact raw tin-stone, or a stone of any other kind.

The species of Cornish tin ores differ from those of Bohemia and Saxony, by containing much less iron, and less arsenic; and this is the cause of the preference the English tin in general obtains above any other tin.

The common matrix of tin in these mines is the killas and the growan. This consists of white clay mixed with mica and quartz, without any particular texture; which when lamellar and hard, is called gneiss by the Germans, and is nothing else but decayed granite, in which the felspar has been broken down to clay.

The zinngrauen from Cornwall. It is the most remarkable, though rare, and consists of quadrangular prisms, or double quadrangular pyramids, joined by their bases, so that these crystals are octoedral; these are found at Trwauance and Soil-hole, in the parish of St. Agnes. Similar prismatic crystals, but of as small a size as a hair, are found in tin-stone upon killas, at Polgooth, one of the richest tin mines, which produces sometimes a clear profit from 1000 to 1200l. per month.

The stream-tin is collected in the valleys of the tin-mountains in Cornwall, and yields a considerable quantity of this metal. The soil is dug several feet deep, and washed by water going over it, till the heavier particles of the ore remain at the bottom. These are nothing else but the abrasions of the tin ores over the mountains, which are rolled down the declivities of the hills to lower grounds.

The stream-tin from Penfagillis is remarkable on account of the native gold now and then met with in it; and found, though very rarely, in pieces of the

\* On Cronstedt, 626.

value of two or three pounds sterling. It principally consists of round, oval, and somewhat smooth pieces, from the size of a bean to that of a pea, and less, whose polished surfaces shew a variety of reddish, grey, light-brown, and dark-yellow colours.

The wood-tin ore looks like hematites, and is found only in the parishes of St. Columb, Roach, and St. Denis. This is without any crystallized form, and has a very inconsiderable quantity of iron with it.

Another wood-like tin ore, described by professor Brunnich, shews various fine fibres converging to different centres, like the radiated zeolyte; but is so compact and hard, as to strike fire with steel. Its specific gravity at the 45° of Fahrenheit is 580, and even 645. It contains some arsenic and a considerable proportion of iron; and gives sometimes 63,5 per cent. of tin. It is very scarce, and found only in small pieces\*.

The tin spar, or white tin ore, is generally of a whitish or gray colour; sometimes it is yellowish, semi-transparent, and crystallized, either of a pyramidal form, or irregular. It is white and semi-transparent, resembling a calcareous or rather ponderous spar, but is easily known by its great weight and shining greasy appearance. Its fracture also is vitreous. It was formerly thought to contain arsenic; but Margraaf found it to be the purest of all tin-ores; though it is said to contain sometimes a mixture of calcareous earth. Its specific gravity is = 6,007.

Tin grains is of a spherical polygonal figure, like the garnets; but seems more unctuous on its surface.

It is found either in large or small grains.

Bergman received a specimen of native aurum musivum from Nerchinskoi in Siberia. It resembled the artificial aurum musivum externally, or rather the aurum musivum formed a crust invironing a nucleus radiated in its fracture, and resembling a white metal. It yielded to the knife, and the place of section exhibited variable colours. Its powder was black. By the analysis, it proved to consist of tin mineralized by sulphur, with a very small portion of copper. In the Journal de Physique for 1783, it is said that the specimen was too small to admit of a determination of the quantities in the large way: but in the preface to the Sciographia it is said that the native aurum musivum contained forty parts of sulphur to one of tin; and the other mineral, which resembled antimony, contained one fifth part of sulphur only.

At Hael Rock, in St. Agnes in Cornwall, there has been found a metallic vein nine feet wide, at twenty yards beneath the surface. Raspe was the first who discovered this to be a sulphurated tin ore: it is very compact, of a blueish-white colour, approaching to gray steel, and similar to the colour of gray copper-ore: it is lamellar in its texture, and very brittle. It consists of sulphur, tin, copper, and some iron. Raspe proposes to call it bell-metal ore.

According to Klaproth's analysis of this ore, 119 grains contain 30 of pure sulphur, 41 of tin, 43 of copper, two of iron, and three grains of the stony matrix. In another specimen of the same sulphurated tin ore from Cornwall, there were in the hundred, 25 parts of sulphur, 34 of tin, 36 of copper, three of iron, and two of the stony matrix.

Bergman's method of assaying tin ores in the humid way is as follows: Let the tin ore, well separated from its stony matrix by washing, and reduced to the

\* This account of the Cornish tin ores is extracted from a treatise of Klaproth by Magellan.



most subtle powder, be digested in concentrated oil of vitriol in a strong heat for several hours; then, when cool, add a small quantity of concentrated marine acid, and suffer it to stand for one or two hours; then add water; and when the solution is clear pour it off, and precipitate it by fixed mineral alkali. One hundred thirty-one grains of this precipitate washed and dried are equivalent to 100 of tin in its reguline state, if the precipitate consists of pure tin; but if it contains copper or iron, it should be calcined for one hour in a red heat, and then digested in nitrous acid, which will take up the copper, and afterwards in marine acid, which will separate the iron.

In the dry way, these ores, after pulverization and separation of the stony matter by washing, are to be melted with a mixture of double their weight of a flux, consisting of equal parts of pitch and calcined borax, in a crucible lined with charcoal, and to which a cover is luted; fusion should be speedily procured.

Bergman recommends a mixture of one part of the ore with two of tartar, one of black flux, and one-half part of rosin: this is to be divided into three parts, and each successively projected into a crucible heated white, and immediately covered after the foregoing portion ceases to flame: the whole operation takes up but seven minutes, or less.

Previous to smelting in the large way, the impure ores of tin must be cleansed as much as is possible from all heterogeneous matters. This cleansing is more necessary in ores of tin than of any other metal, because in the smelting of tin ores a less intense heat must be given than is sufficient for the scorification of earthy matters; lest the tin be calcined. Tin ores previously bruised may be cleansed by washing, for which operation their great weight and hardness render them well adapted. If they be intermixed with very hard stones or ferruginous ores, a slight roasting will render these impure matters more friable, and consequently fitter to be separated from the tin ores. Sometimes these operations, the roasting, contusion, and lotion, must be repeated. By roasting, the ferruginous particles are so far revived, that they may be separated by magnets.

The ore, thus cleansed from adhering heterogeneous matters, is to be roasted in an oven or reverberatory furnace with a fire rather intense than long continued, during which it must be frequently stirred to prevent its fusion. By this operation the arsenic is expelled, and in some works is collected in chambers built purposely above the calcining furnace.

Lastly, the ore cleansed and washed is to be fused, and reduced to a metallic state. In this fusion, attention must be given to the following particulars: 1. No more heat is to be applied than is sufficient for the reduction of the ore, because this metal is fusible with very little heat, and is very easily calcinable. 2. To prevent this calcination of the reduced metal, a larger quantity of charcoal is used in this than in the other fusions. 3. The scoria must be frequently removed, lest some of the tin should be involved in it, and the melted ore must be covered with charcoal powder to prevent the calcination of its surface. 4. No flux or other substance, excepting the scoria of former smeltings which contains some tin, are to be added, to facilitate the fusion.

**ORES OF URANITE, OR URANIUM.** See URANITE.

**ORES OF WOLFRAM.** See WOLFRAM.

**ORES OF ZINC.** This metal has not been found in a native state.

All the ores of zinc tinge plates of copper of a yellow colour, when stratified with that metal and charcoal; but for this purpose the sulphureous ores must be previously roasted. Of the calciform ores of zinc, Kirwan makes four varieties.

**VARIETY I.** The vitreous zinc ore, or zinc spar, is a pure calx of zinc, of a whitish-gray, blueish-gray, or yellowish colour, and of a hardness generally sufficient to strike fire with steel; in its fracture it resembles quartz; irregular, stalactitical or crystallized in groups, and weighty; by calcination it loses one-third of its weight, without emitting a sulphureous or arsenical smell, and is infusible in the strongest heat either singly or with mineral alkali, but easily fusible with borax or microcosmic salt. In the mineral acids it is soluble with effervescence, and with the vitriolic affords vitriol of zinc. One hundred grains of this ore contain about 65 of the calx of zinc, 28 of aerial acid, six of water, and one of iron, and sometimes a little of filex.

Bergman suspects the substance called zinc spar by Baron Born to be a different substance. Bindheim found it insoluble in acids before calcination, and in the dry way infusible with the three usual fluxes, but after calcination it becomes soluble in acids\*.

**VARIETY II.** Tutenago, or the calx of zinc mixed with a notable proportion of iron. Engestrom, in the Memoirs of Stockholm for the year 1775, has given us an analysis of an ore of this sort from China; it was of a white colour, interspersed with red streaks of calx of iron, and so brittle as to be easily broken betwixt the fingers. In the dry way it exhibited the same appearances as the former variety, except that it lost no part of its weight; it was soluble in the mineral acids, particularly with the assistance of heat, and with the vitriolic afforded vitriol both of zinc and iron; the quantity of fixed air was so small as to be absorbed by the solution; it contained in various specimens from 60 to 90 per cent. of zinc; the remainder was iron and a small proportion of argill. Bindheim also discovered this variety in Germany, and found it to consist of zinc, a little iron, and filex†.

**VARIETY III.** Calamine. In this ore the calx of zinc is mixed with iron and clay in various proportions. Its colour is white, gray, yellow, brown or red, not so brittle as the second variety, and of various degrees of hardness, though scarce ever so hard as to strike fire with steel; its texture equable or cellular, and its form either irregular, crystallized or stalactitical; when calcined it loses no part of its weight, except it be mixed with charcoal, and then flowers of zinc sublime; it is soluble in acids, and with the vitriolic affords vitriol of iron as well as of zinc, which shews the iron it contains is not much calcined. The specific gravity of the best sort, that is, the gray, is 5,000 : 100 parts of this afforded Bergman 84 of calx of zinc, three of iron, one of argill, and 12 of filex; but in other specimens these proportions are very different; some ores are so poor as not to contain above 4 per cent. of calx of zinc; a good ore should afford at least 30 per cent. and its specific gravity be about 4,400 or 5,000.

Sometimes calamines contain a mixture of calcareous earth and lead. 3 Lin. von Gmel. 112. Most of the English calamines contain lead.

The first and second varieties are easily analysed in the moist way, by dissolving them in the dilute vitriolic acid; the filex, if any, will remain undissolved, and the zinc and iron are taken up, and may be separated by adding a piece of zinc previously weighed, and boiling the solution; the iron will be precipitated; the solution, which then contains only zinc, should be precipitated by aerated mineral alkali. One hundred ninety-three grains of this precipitate are equivalent to 100 of zinc in its metallic form, from which the weight lost by the inserted zinc

\* 4 Berlin Schrift. 399. Quoted by Kirwan. † 4 Berl. Schrift. 400. Quoted by Kirwan.

should



should be subtracted; the weight of the fixed air and water may be collected by comparing the loss of weight which the ore suffers by calcination and solution in acids.

The analysis of the third variety, or calamine, is more complex. Bergman gives us two methods of performing it. The first is to dephlogisticate it in the nitrous acid with the assistance of heat, and boil away the acid to dryness. Repeat this operation twice or thrice, using each time twice as much of the acid as the ore weighs; and lastly, dissolve all that is soluble in a fresh portion of nitrous acid: by this means the zinc (and lead if any) with the argill will be taken up, while the iron, being dephlogisticated, will with the filix remain undissolved: if the solution contains lead, the marine acid will precipitate it; after which the vitriolic may be used to precipitate the calcareous earth, if any be contained in the ore, or the lead and other metals may be precipitated by adding a piece of zinc. The zinc may then be precipitated by the Prussian alkali, the weight of which divided by five gives that of zinc in its metallic form contained in the ore. The undissolved residuum should be treated with three times its weight of concentrated vitriolic acid, and evaporated to dryness, and all that is soluble extracted with warm water; the iron should be precipitated by the Prussian alkali, and the argill by the aerated mineral alkali, which should also be added to the nitrous solution after the zinc is precipitated.

The second method is shorter and more ingenious. He distills the vitriolic acid over calamine to dryness; the residuum he lixiviates in hot water; what remains undissolved is filix; to the solution he adds a caustic volatile alkali, which precipitates the iron and argill, but keeps the zinc in solution, as it is soluble in vitriolic ammoniac; the precipitate he re-dissolves in vitriolic acid, and separates the iron and argill as before.

VARIETY IV. Zeolytiform. In this ore, the calx of zinc is mixed with a notable proportion of filix. The real contents of this substance were first discovered by M. Pelletier, a most accurate Parisian chemist. It was long taken for a zeolyte, being of a pearl colour, crystallized, semi-transparent, consisting of laminæ diverging from different centres, and becoming gelatinous with acids. It was commonly called zeolyte of Friburgh: he found 100 grains of it to contain from 48 to 52 of quartz, 36 of calx of zinc, and eight or 12 of water.

Of the ores of zinc which are mineralized by sulphur, by means of iron, there are, according to Kirwan, seven varieties. These are generally of a lamellar or scaly texture, and frequently of a quadrangular form, resembling galena; they all lose much of their weight when heated, and burn with a blue flame; their specific gravity is inferior to that of galena. Almost all contain a mixture of lead ore; most of them exhale a sulphureous smell when scraped, or at least when vitriolic or marine acid is dropped on them.

VARIETY I. is of a blueish-gray colour, and of a metallic appearance. Its form is generally cubical or rhomboidal, its texture scaly or steel-grained; by calcination it loses nearly  $\frac{1}{6}$  of its weight; after calcination it is more easily soluble in the mineral acids. One hundred parts of it afforded Bergman about 52 of zinc, eight of iron, four of copper, 26 of sulphur, four of water, and six of filix.

To analyse this ore in the moist way, Bergman first expelled the water and part of the sulphur by distillation; the residuum he treated with three times its weight of oil of vitriol evaporated to dryness; this lixiviated with warm water, left only

six parts undissolved; in this solution a polished plate of iron was boiled, which precipitated the copper. He then by means of the phlogisticated alkali precipitated the zinc and iron. This precipitate being calcined in an open fire, was several times treated with nitrous acid evaporated to dryness, till the iron was perfectly dephlogisticated; fresh nitrous acid being then added, dissolved the zinc only, which being precipitated by the Prussian alkali, the proportion of zinc, in its metallic state, was found as in the analysis of the third variety of the calciform ores. Neither metal as contained in the ore is much dephlogisticated.

VARIETY II. is black, Pechblende. This ore is of moderate hardness, does not give fire with steel, frequently crystallized, and then sometimes transparent, or semi-transparent; when pulverized, it gives a reddish powder; when heated, it decrepitates; and if laid on a burning coal, it emits a sulphureous smell, and depose white and yellow flowers; it is not magnetic even after torrefaction, but loses 25 per cent. of its weight. It is frequently mixed with silver, arsenic, and other metals. One hundred parts of that of Danemora, examined by Bergman, exhibited 45 of zinc, one of regulus of arsenic, nine of iron, six of lead, all slightly dephlogisticated, 29 of sulphur, six of water, and four of filix.

This ore he analysed in the moist way after the following manner: First, by distillation he obtained the water, regulus of arsenic, and part of the sulphur; the residuum he boiled in marine acid, until all that was soluble was taken up. To the solution, after its filtration and some evaporation, he added vitriolic ammoniac, by whose decomposition vitriol of lead was precipitated in some measure, and the remainder of it by further evaporation. This being separated, the remainder was evaporated to dryness, and treated with nitrous acid, and at last calcined to dephlogisticate the iron; the calx of zinc only was then dissolved in the nitrous acid, and precipitated by the Prussian alkali.

VARIETY III. is red, or reddish; and is the Röd Slag of the Swedes. Its texture is generally scaly, sometimes crystallized, and semi-transparent; it gives fire with steel; it does not decrepitate nor smoke when heated, yet it loses about 13 per cent. of its weight by torrefaction.

One hundred parts of that of Sahlberg contained, by Bergman's analysis, 44 of zinc, five of iron, 17 of sulphur, five of water, five of argill, and 24 of quartz.

In analysing this ore, the water and sulphur were obtained as before; nitrous acid was several times distilled to dryness over the residuum, which was at last calcined, and again treated with the nitrous acid, which then left the iron and quartz and a little argill undissolved; the Prussian alkali precipitated the zinc from this solution, and after that, the aerated volatile alkali precipitated the argill. The undissolved residuum was treated with oil of vitriol dissolved to dryness, which took up the calx of iron, and a small proportion of argill. The Prussian alkali precipitated the iron, and the liquor being then evaporated, afforded a little alum and tartar vitriolate.

VARIETY IV. is phosphorescent blende. Its colour is generally greenish, yellowish-green, or red, of different degrees of transparency, or opaque; when scraped with a knife in the dark, it emits light, even in water; and after undergoing a white heat, when distilled per se, a filiceous sublimate rises, which shews it contains the sparry acid, probably united to a metal, since it sublimes. It is almost wholly soluble in the marine acid in a boiling heat.

Bergman found 100 parts of that of Scharfenberg to contain 64 of zinc, five of iron, 20 of sulphur, four of fluor acid, six of water, and one of filix.

VARIETY



VARIETY V. is grayish-yellow blende. This consists of a mixture of blende, galena, and petrol; it contains about 24 per cent. of zinc; it is probably the same as the gray blende of Monnet. Mineral. p. 400.

VARIETY VI. is white blende; and is found at Silverberget.

VARIETY VII. is yellow blende. This ore is of the colour of wax, and semi-transparent, and contains much sulphur.

In the dry way zinc is reduced by distilling its ore after torrefaction, with a mixture of its own weight of charcoal, in an earthen retort well luted, and a strong heat; but by this method scarce half the zinc it contains is obtained.

The first dressing of calamine for the large works of zinc consists in picking out all the pieces of lead ore, lime, and iron-stone, cauk, and other heterogeneous substances, which are found mixed with it in the mine: it is then calcined in proper furnaces, where it loses about a fourth or third part of its weight. It is picked out again very carefully, as the heterogeneous particles have become more discernible, by the action of the fire; it is then ground to a fine powder, and washed in a gentle rill of water, which carries off the earthy mixtures of extraneous matters; so that, by these processes, a ton weight of the crude calamine of Derbyshire is reduced to 1200 only.

Bergman affirms, that a certain Englishman, whose name he does not mention, made, several years ago, a voyage to China, for the purpose of learning the art of smelting zinc, or tutenago; and that he became instructed in the secret, and returned safely home.

It is not improbable, but that a fact of this kind may have served to establish the manufactory of zinc in England about the year 1743, when Mr. Champion obtained a patent for the making of it, and built the first work of the kind near Bristol. It consists, as Watson relates, of a circular kind of oven, like a glass-house furnace, in which were placed six pots, of about four feet each in height, much resembling large oil-jars in shape; into the bottom of each pot is inserted an iron tube, which passes through the floor of the furnace, into a vessel of water. A mixture of the prepared ore is made with charcoal, and the pots are filled with it to the mouth, which are then close stopped with strong covers, and luted with clay. The fire being properly applied, the metallic vapour of the calamine issues downwards, or per descensum, through the iron tubes, there being no other place through which it can escape; and the air being excluded, it does not take fire, but is condensed in the water into granulated particles; which being remelted, are cast into ingots, and sent to Birmingham under the name of zinc or spelter; although by this last name of spelter, only a granulated kind of soft brass is understood among the braziers, and others who work in London, used to solder pieces of brass together.

Great part of the zinc volatilized by the force of fire, in large furnaces, as those at Goslar, adheres to their sides in the form of a whitish calx; this is scraped off when the furnace is cold, and is called by the name of ofenbruch or cadmia, which is employed, as well as zinc, to make brass.

ORIENTAL. Precious stones from the East have been supposed to be harder and more brilliant than those which come from South America. How far this may really be the case, is not perhaps easy to be determined. Jewellers use the words oriental and occidental to denote the superior or inferior quality of a gem, without giving themselves any trouble about the place it came from. Thus an oriental topaz is one of the best, whether it come from the East Indies or

or not; and the inferior stones or coloured quartz are called occidental topazes, though some of them perhaps may come from the East.

**ORIGANUM.** An essential oil is kept in the shops, under the name of the oil of origanum, which is obtained from the leaves of the *origanum vulgare* Linnæi, or wild marjoram.

**ORPIMENT.** A combination of the calx of arsenic with sulphur, of a yellow colour. It is naturally found in the earth, generally of an irregular form, and composed of shining, flexible laminae, more or less solid. Its specific gravity, according to Kirwan, is about 5,315, who asserts, that it contains about one tenth of its weight of sulphur.

The same author asserts, that the realgar, or red combination of arsenic and sulphur, contains 16 parts of the latter in the hundred, and has no greater specific gravity than 3,225. This is either opaque or semi-transparent; sometimes transparent, and regularly crystallized, in octohedral pyramids or prisms. In this last form it is called ruby of arsenic. Chaptal, however, observes from Bucquet, that the difference between orpiment and realgar does not consist in the proportion of their component parts, but simply in the latter having undergone a greater heat, nothing more being necessary in order to convert orpiment into realgar than exposure to a strong heat; and with the same mixture we may at pleasure obtain either of these products, according to the manner of applying the heat. This fact appears to resemble the conversion of mercurial ethiops into cinnabar. See CINNABAR.

**ORRIS.** The dry roots of the Florence iris or oris (*iris alba Florentina*, C. B.) are entirely mild, and said to be a medicine of good service in disorders of the breast. They have a pleasant sweet smell resembling that of violets, and hence are employed in sweet-scented powders, for flavouring liquors, &c. The distilled water smells a little of the root, but exhibits no appearance of oil; the distilled spirit also has some slight smell. The strongest preparation both in smell and taste, is the spirituous extract, this containing nearly all the active parts of the root concentrated into a small volume. An ounce of the root yielded a dram and 17 grains of spirituous, and afterwards a dram and 40 grains of watery extract: water applied at first extracted from the same quantity three drams, and spirit afterwards only eight grains. The extract made by water at first both tastes and smells of the orris, though not near so strongly as the spirituous.

**OSTEOCOLLA** is a substance formed by stony matters filling up the interstices of rotten roots of trees. It has been particularly described by Mr. Gleditsch, and examined chemically by Mr. Margraaf. See Memoirs of the Berlin Academy for the year 1748. The former author relates, that it is dug from grounds containing fine sand and a fine calcareous earth; and that sometimes the roots of living trees had been found converted into this stony substance. From Margraaf's experiments it appears, that the osteocolla examined by him was composed of a fine sand, a fine calcareous earth, and some rotten remains of a root. Neumann says, that he found marine acid in osteocolla. But nothing of that or any other acid could be discovered by Margraaf. Neumann also says, that he totally dissolved osteocolla by means of dilute vitriolic acid. Hence the substances examined by these two chemists seem to have been different. Differences must arise from the different qualities of the soil in which osteocolla is found.



**OTTA or ATYR OF ROSES.** The essential oil of roses. It comes to us under this name from Bengal, and is of too high price to become an article of commerce in this country. From a variety of accounts we learn that it is obtained in the usual method, viz. by the distillation of rose leaves with water, and that a prodigious quantity of roses affords but a small proportion of the oil. It is said to be equal in fragrance to a new blown rose. This may perhaps be true of the oil when newly distilled; but in the few specimens which have come under my observation, the difference in scent appears to be nearly as great as between most other essential oils and the vegetables which afford them.

**OXYGENE.** See NOMENCLATURE.

**OXYMEL.** A compound of honey and vinegar, usually with other medicinal ingredients.

## P

### P A L

### P A N

**PALM-OIL.** This is obtained from the kernels of the fruit of a species of palm-tree, which is a native of the coast of Guinea and Cape de Verde Islands, whence it has been transplanted into Jamaica and Barbadoes. The oil as it comes to us is about the consistence of an ointment, and of an orange colour; of a strong though not disagreeable smell, and very little taste. By long keeping it loses its colour and becomes white, when it ought to be rejected. It is used in external applications, and also as a purgative medicine.

**PANACEA.** This name, which signifies universal remedy, has been given to various preparations. The panacea of antimony was formed by detonation in small portions at a time in a red-hot crucible, a mixture of six parts, by weight, of crude antimony, two of nitre, one and a half of common salt, and one of charcoal. The mass when fused and poured out consists of regulus of antimony at bottom; an hepatic compound in the next place; and at top, a spongy mass. This last, when pulverized, washed, and dried, is of a golden yellow colour, and is the panacea. It was given in pills containing from one tenth to one third of a grain of the powder, and is said to operate gently as a cathartic and emetic.

We have several mercurial panaceas. The red panacea is made by washing the red calx of mercury, obtained by nitrous acid and calcination; then digesting it for many days in ardent spirit; next, burning off from it a portion of tincture of sulphur; and lastly, digesting it again in ardent spirit for some days.

The white panacea consists of calomel on which ardent spirit has been digested, and which is afterwards, according to some prescriptions, to be repeatedly sublimed.

Modern.

Modern chemistry has rejected these inartificial, troublesome, and at best, useless processes.

The magnesian earth obtained by precipitation from the mother water of nitre, was called the nitrous panacea.

**PAPER-MARLE.** See **MARLE**.

**PARGET.** The plaster stone or calcareous earth combined with vitriolic acid.

**PARIAN MARBLE.** A fine white Italian marble, which is never polished when wrought, but only finely ground down. It has a glittering texture, and is slightly transparent at the edges. Cronstedt considers it as a limestone, that is, lime combined with fixed air and water.

**PARTING**, is an operation by which gold and silver are separated from each other. As these two metals resist equally well the action of fire and of lead, they must therefore be separated by other methods. This separation could not be effected, if they were not soluble by different menstruums.

Nitrous acid, marine acid, and sulphur, which cannot dissolve gold, attack silver very easily; and therefore these three agents furnish methods of separating silver from gold, or of the operation called parting.

Parting by nitrous acid is the most convenient, and therefore most used, and even almost the only one employed by goldsmiths and coiners. Wherefore it is called simply parting. That made with the marine acid is only made by cementation, and is known by the name of concentrated parting. Lastly, parting by sulphur is made by fusion, which the chemists call the dry way, and is therefore called dry parting. We shall describe each of these methods\*.

**PARTING BY AQUA FORTIS.** Although parting by aqua fortis be easy, as we have said, it cannot succeed, or be very exact, unless we attend to some essential circumstances.

1. The gold and silver must be in a proper proportion; for if the gold be in too great quantity, the silver would be covered and guarded by it from the action of the acid.

Therefore when assayers do not know the proportion of these two metals in the mass to be operated on, they discover it by the touch, or assay needles. See **ASSAY**.

If this trial shews, that in any given mass the silver is not to the gold as three to one, this mass is improper for the operation of parting by aqua fortis. In this case, the quantity of silver necessary to make an assay of that proportion must be added.

This operation is called quartation, probably because it reduces the gold to a fourth part of the whole mass.

2. That the parting may be exact, the nitrous acid or aqua fortis employed must be very pure, and especially free from mixture of vitriolic and marine acids. Its purity must therefore be ascertained; and if this be found not sufficient, the acid must be purified by solution of silver. See **ACID OF NITRE**, p. 32.

If the purity of the aqua fortis were not attended to, a quantity of silver proportionable to these two foreign acids would be separated during the solution; and this portion of silver converted by these acids to vitriol of silver, and to luna cornea, would remain mingled with the gold, which consequently would not be entirely purified by the operation.

\* From Macquer.



When the metallic mass is properly allayed, it is to be reduced to plates, rolled up spirally, called cornets; or to grains. These are to be put into a matrafs, and upon them a quantity of aqua fortis is to be poured, the weight of which is to that of the silver as three to two: and as the nitrous acid employed for this operation is rather weak, the solution is assisted, especially at first, by the heat of a sand-bath, in which the matrafs is to be placed. When, notwithstanding the heat, no further mark of solution appears, the aqua fortis charged with silver is to be decanted. Fresh nitrous acid is to be poured into the matrafs, stronger than the former, and in less quantity, which must be boiled on the residuous mass, and decanted as the former. Aqua fortis must even be boiled a third time on the remaining gold, that all the silver may be certainly dissolved. The gold is then to be washed with boiling water. This gold is very pure, if the operation has been performed with due attention. It is called gold of parting.

No addition of silver is required, if the quantity of silver of the mass is evidently much more considerable than that of the gold: persons who have not proof needles, and other apparatus to determine the proportion of the alloy, may add to the gold an indeterminate quantity of silver, observing that this quantity be rather too great than too small, and so considerable as to render the mass nearly as white as silver; for a large quantity of silver is rather favourable than hurtful to the operation: it has no other inconvenience than an useless expence, as the larger the quantity is of silver, the more aqua fortis must be employed. We ought to attend to this fact, that the colour of gold is scarcely perceptible in a mass two-thirds of which is silver and one-third is gold; this colour then must be much less perceptible when the gold is only one-fourth part, or less, of the whole mass.

If the quantity of gold exceeds that of the silver, the mass may be exposed to the action of aqua regia, which would be a kind of inverse parting, because the gold is dissolved in that menstruum, and the silver is not, but rather reduced to a luna cornea, which remains in form of a precipitate after the operation. But this method is not much practised, for the following reasons.

First, the gold cannot be easily separated from the aqua regia; for if the parting has been made with an aqua regia prepared with sal ammoniac, or if the gold be precipitated by a volatile alkali, this gold has a fulminating quality, and its reduction requires particular operations. If the aqua regia has been made with spirit of salt, and the precipitation effected by a fixed alkali, the gold will not then be fulminating, but the precipitation will be very slow, and probably not complete. See GOLD.

Secondly, in the parting by aqua regia, the silver is indeed precipitated into a luna cornea, and thus separated; but this separation is not perfect, as a small quantity of luna cornea will always remain dissolved by the acids, if this solution even could only be effected by the superabundant water of these acids. Accordingly the silver is not so accurately separated from the gold by aqua regia, as the gold is from the silver by aqua fortis. We shall afterwards see, at the article PARTING (CONCENTRATED), that by this operation, silver may be separated from gold in the dry way without the necessity of quartation, although these metals should not be in a proper proportion for the parting by aqua fortis.

The gold after the parting by aqua fortis is much more easily collected when it remains in small masses, than when it is reduced to a powder.

When the mass has been regularly quarted; that is, when it contains three parts

parts of silver and one part of gold, we must employ, particularly for the first solution, an aqua fortis so weakened, that heat is required to assist the solution of the silver: by which means the solution is made gently; and the gold which remains preserves the form of the small masses before the solution. If the aqua fortis employed were stronger, the parts of the gold would be disunited, and reduced to the form of a powder, from the activity with which the solution would be made.

We may indeed part by aqua fortis a mass containing two parts of silver to one part of gold; but then the aqua fortis must be stronger; and if the solution be not too much hastened, the gold will more easily remain in masses after the operation. In both cases, the gold will be found to be tarnished and blackened. Its parts have no adhesion together, because the silver dissolved from it has left many interstices; and the cornets or grains of this gold will be easily broken, unless they be handled very carefully. To give them more solidity, they are generally put into a test under a muffle, and made red-hot, during which operation they contract considerably, and their parts are approximated. These pieces of gold are then found to be rendered much more solid, so that they may be handled without being broken. By this operation also the gold resumes its colour and lustre; and as it generally has the figure of cornets, it is called gold in cornets, or grain gold. Essayers avoid melting it, as they choose to preserve this form, which shews that it has been parted.

The gold and silver thus operated upon ought to have been previously refined by lead, and freed from all alloy of other metallic matters, so that the gold which remains should be as pure as is possible. However, as this is the only metal which resists the action of aqua fortis, it might be purified by parting from all other metallic substances; but this is not generally done for several reasons. First, because the refining by lead is more expeditious and convenient for the separation of the gold from the imperfect metals; and secondly, because the silver, when afterwards separated from the aqua fortis, is pure; lastly, because most imperfect metals do not remain completely and entirely dissolved in nitrous acid, from the degree of calcination produced in them by this acid, the gold would be found, after the parting, mixed with the part of these metals which is precipitated.

The gold remaining after the parting ought to be well washed, to cleanse it from any of the solution of silver which might adhere to it; and for this purpose distilled water ought to be used, or at least water the purity of which has been ascertained by its not forming a precipitate with a solution of silver, because such a precipitate would alter the purity of the gold.

The silver dissolved in the aqua fortis may be separated either by distillation, in which case all the aqua fortis is recovered very pure, and fit for another parting; or it may be precipitated by some substance which has a greater affinity than this metal with nitrous acid. Copper is generally employed for this purpose at the mint.

The solution of silver is put into copper vessels. The aqua fortis dissolves the copper, and the silver precipitates. When the silver is all precipitated, the new solution is decanted, which is then a solution of copper. The precipitate is to be well washed, and may be melted into an ingot. It is called parted silver. When this silver has been obtained from a mass which had been refined by lead, and when it has been well washed from the solution of copper, it is very pure.

Cramer justly observes, in his Treatise on Essaying, that however accurately



the operation of parting has been performed, a small portion of silver always remains united with the gold, if the parting has been made by aqua fortis; or a small portion of the gold remains united with the silver, if the parting has been made by aqua regia; and he estimates this small alloy to be from a two hundredth to a hundred and fiftieth part, which quantity may be considered as nothing for ordinary purposes, but may become sensible in accurate chemical experiments.

The mass of gold and silver to be parted, ought previously to be granulated, which may be done by melting it in a crucible, and pouring it into a large vessel full of cold water, while at the same time a rapid circular motion is given to the water by quickly stirring it round with a stick or broom.

The vessels generally used for this operation, called parting-glasses, have the form of truncated cones, the bottom being commonly about seven inches wide, the aperture about one or two inches wide, and the height about twelve inches. These glass vessels ought to have been well annealed, and chosen free from flaws; as one of the chief inconveniences attending the operation is, that the glasses are apt to crack, by exposure to cold, and even when touched by the hand. Some operators secure their glasses by a coating. For this purpose, they spread a mixture of quick-lime flaked with beer and whites of eggs upon linen cloth, which they wrap round the lower part of the vessel, leaving the upper part uncovered, that they may see the progress of the operation, and over this cloth they apply a composition of clay and hair. Schlutter advises to put the parting-glasses in copper vessels containing some water, and supported by trevets, with fire under them. When the heat communicated by the water is too great, it may be diminished by adding cold water, which must be done, very carefully, by pouring against the sides of the pan, to prevent too sudden an application of cold to the parting-glass. The intention of this contrivance is, that the contents of the glasses, if these should break, may be received by the copper vessel. Into a glass fifteen inches high, and ten or twelve inches wide at bottom, placed in a copper pan twelve inches wide at bottom, fifteen inches wide at top, and ten inches high, he usually put about eighty ounces of metal, with twice as much aqua fortis.

The aqua fortis ought to be so strong as to be capable of acting sensibly on silver when cold, but not so strong as to act violently.

If the aqua fortis be very strong, however pure, and if the vessels be well closed, a small quantity of the gold will be dissolved along with the silver, which is to be guarded against.

Little heat ought to be applied at the beginning, the liquor being apt to swell, and rise over the vessel; but when the acid is nearly saturated, the heat may be safely increased.

When the solution ceases, which may be known by the discontinuance of the effervescence, or emission of air-bubbles, the liquor is to be poured off. If any grains appear entire, more aqua fortis must be added, that all the silver may be dissolved. If the operation has been performed slowly, the remaining gold would have still the form of distinct masses, which are to receive solidity and colour by fire, as Macquer directs. If the operation has been performed hastily, the gold will have the appearance of a black mud or powder, which after five or six washings with pure water must be melted.

The silver is usually recovered by precipitating it from the aqua fortis by means of copper vessels into which the liquor is poured, or of plates of copper which are thrown along with the liquor into glass vessels. A considerable heat is required to accelerate this precipitation. Dr. Lewis says, he has observed, that when

when the aqua fortis was perfectly saturated with silver, no precipitation was occasioned by plates of copper, till a drop or two of aqua fortis was added to the liquor, and then the precipitation began and continued as usual.

The precipitated silver must be well washed in boiling water, and fused with some nitre, the use of which is, to scorify any cupreous particles which may adhere to the silver.

From the solution of copper in aqua fortis, a blue pigment, called verditer, is obtained by precipitation with whiting. See VERDITER.

**PARTING (CONCENTRATED.)** Concentrated parting is also called parting by cementation, because it is actually performed by cementation. This parting or purification of gold is used when the quantity of it is so great in proportion to the silver, that it cannot be separated by aqua fortis. This operation is performed in the following manner :

A cement is first prepared, composed of four parts of bricks powdered and sifted, of one part of green vitriol calcined till it becomes red, and of one part of common salt. The whole is very accurately mixed together, and a firm paste is made of it by moistening it with a little water or urine. This cement is called cement royal, because it is employed to purify gold, which is considered by chemists as the king of metals.

The gold to be cemented is to be reduced to plates as thin as small pieces of money. At the bottom of the crucible, or cementing pot, a stratum of cement, of the thickness of a finger, is to be put, which is covered with plates of gold : upon these another stratum of cement is to be laid; and then more plates of gold, till the crucible or pot is filled with these alternate strata of cement and of gold. The whole is then to be covered with a lid, which is to be luted with a mixture of clay and sand. This pot is to be placed in a furnace, or oven, and heated by degrees, till it is moderately red, which heat is to be continued during twenty-four hours. The heat must not be so great as to melt the gold. The pot or crucible is then left to cool, and the gold is to be carefully separated from the cement, and boiled at different times in a large quantity of pure water. This gold is to be essayed upon a touch-stone or otherwise; and if it be found not sufficiently purified, it is to be cemented a second time in the same manner.

The acid of the common salt is disengaged during this cementation, and dissolves the silver allayed with the gold, by which means it is separated.

This experiment proves, that although marine acid while it is liquid cannot attack silver, it is nevertheless a powerful solvent of that metal. But, for this purpose, it must be applied to the silver in the state of vapours extremely concentrated, and assisted with a considerable heat. All these circumstances are united in the concentrated parting.

This experiment proves also, that notwithstanding all these circumstances, which favour the action of the marine acid, it is incapable of dissolving gold.

Lastly, the marine acid in this state more effectually dissolves the silver than the nitrous acid does in the parting by aqua fortis, since this operation succeeds well when the silver is in so small a proportion as that it would be protected from the action of the nitrous acid in the ordinary parting.

Instead of sea salt, nitre may be used with equal success; because the nitrous acid is then put in a state to attack the silver, notwithstanding the quantity of gold which covers it.

Several chemists and artists use both nitre and common salt in the cement royal; which shews that the acid of aqua regia, if produced and applied in this manner



at the same time to gold and silver, attacks the latter metal preferably to the former. By this method some of the gold would probably be dissolved along with the silver. As no advantages are said to attend it, to give it preference to cementation with nitre or with sea salt singly, Dr. Lewis judiciously disapproves of it.

The gold must be very carefully washed after the operation to cleanse it from particles of dissolved silver, which otherwise would stick to it.

The silver may be separated from the cement by fusion with a sufficient quantity of lead and litharge, and by cupelling the lead which retains the silver.

Gold is never purified by one operation of this kind. It must therefore be again melted, beat into plates, and cemented as before. The operation is troublesome, and is now little used, except by artists in the small way, for extracting silver or base metals from the surface of gold, and thus giving to an alloyed metal the colour and appearance of pure gold.

**PARTING (DRY).** Dry parting, or parting by fusion, is performed by sulphur, which has the property of uniting easily with silver, while it does not attack gold.

This method of separating these two metals would be the cheapest, the most expeditious and convenient of any, if the sulphur could dissolve the silver, and separate it from the gold as well and as easily as nitrous acid does: but, on the contrary, we are obliged to employ particular treatment, and a kind of concentration, to begin the union of the sulphur with the silver alloyed with gold. Then repeated and troublesome fusions must be made, in each of which we are obliged to add different intermediate substances, and particularly the metals which have the strongest affinity with sulphur, to assist the precipitation, which in that case does not give a regulus of pure gold, but a gold still alloyed with much silver, and even with a part of the precipitating metals; so that, to complete the operation, cupellation is necessary, and also parting by aqua fortis.

Hence Macquer infers, that this operation ought not to be made but when the quantity of silver with which the gold is alloyed is so great, that the quantity of gold which might be obtained by the ordinary parting is not sufficient to pay the expences, and that it is only proper for concentrating a larger quantity of gold in a smaller quantity of silver. As this dry parting is troublesome, and even expensive, it ought not to be undertaken but on a considerable quantity of silver alloyed with gold. Accordingly, Cramer, Schlutter, Schindler, and all good chemists and artists who have given processes for the dry parting, recommend its use only in the abovementioned cases: it would be much more advantageous, if it could be done by two or three fusions, and if by these an exact separation could be obtained of a small quantity of gold mixed with a large quantity of silver.

The most advantageous method of separating a small portion of gold \* from a large one of silver appears to be by means of sulphur, which unites with and scorifies the silver without affecting the gold: but as sulphurated silver does not flow thin enough to suffer the small particles of gold diffused through it to reunite and settle at the bottom, some addition is necessary for collecting and carrying them down.

In order to the commixture with the sulphur, fifty or sixty pounds of the mixed metal, or as much as a large crucible will receive, are melted at once, and reduced into grains by lading out the fluid matter, with a small crucible made red-hot, and pouring it into cold water stirred with a rapid circular motion. From an

\* Keir's Notes to Macquer's Dictionary.

eighth to a fifth of the granulated metal, accordingly as it is richer or poorer in gold, is reserved; and the rest well mingled with an eighth of powdered sulphur. The grains enveloped with the sulphur are again put into the crucible, and the fire kept gentle for some time, that the silver, before it melts, may be thoroughly penetrated by the sulphur: if the fire were hastily urged, great part of the sulphur would be dissipated without acting upon the metal.

If to sulphurated silver in fusion pure silver be added, the latter falls to the bottom, and forms there a distinct fluid, not miscible with the other. The particles of gold, having no affinity with the sulphurated silver, join themselves to the pure silver, wherever they come in contact with it, and are thus transferred from the former into the latter, more or less perfectly according as the pure silver was more or less thoroughly diffused through the mixed. It is for this use that a part of the granulated metal was reserved. The sulphurated mass being brought into perfect fusion, and kept melted for near an hour in a close covered crucible, one third of the reserved grains is thrown in; and as soon as this is melted, the whole is well stirred, that the fresh silver may be distributed through the mixed, to collect the gold from it. The stirring is performed with a wooden rod; an iron one would be corroded by the sulphur, so as to deprive the mixed of its due quantity of sulphur, and likewise render the subsequent purification of the silver more troublesome. The fusion being continued an hour longer, another third of the unsulphurated grains is added, and an hour after this the remainder; after which the fusion is further continued for some time, the matter being stirred at least every half hour from the beginning to the end, and the crucible kept closely covered in the intervals.

The sulphurated silver appears in fusion of a dark brown colour: after it has been kept melted for a certain time, a part of the sulphur having escaped from the top, the surface becomes white, and some bright drops of silver, about the size of peas, are perceived on it. When this happens, which is commonly in about three hours after the last addition of the reserved grains, sooner or later according as the crucible has been more or less closely covered, and the matter more or less stirred, the fire must be immediately discontinued; for otherwise more and more of the silver, thus losing its sulphur, would subside and mingle with the part at the bottom in which the gold is collected. The whole is poured out into an iron mortar greased and duly heated; or if the quantity is too large to be safely lifted at once, a part is first laded out from the top with a small crucible, and the rest poured into the mortar. The gold, diffused at first through the whole mass, is now found collected into a part of it at the bottom, amounting only to about as much as was reserved unsulphurated. This part may be separated from the sulphurated silver above it by a chisel and hammer; or more perfectly, the surface of the lower mass being generally rugged and unequal, by placing the whole mass with its bottom upwards in a crucible: the sulphurated part quickly melts, leaving unmelted that which contains the gold, which may thus be completely separated from the other. The sulphurated silver is essayed, by keeping a portion of it in fusion in an open crucible, till the sulphur is dissipated; and then dissolving it in aqua fortis. If it should still be found to contain any gold, it is to be melted again; as much more unsulphurated silver is to be added as was employed in each of the former injections, and the fusion continued about an hour and a half.

The gold thus collected into a part of the silver may be further concentrated into a smaller part, by granulating the mass and repeating the whole process.



The operation may be again and again repeated, till so much of the silver is separated, that the remainder may be parted by aqua fortis, without too much expence.

The foregoing process, according to Mr. Schlutter, is practised at Rammelsberg, in the lower Hartz. The prevailing metal in the ore of Rammelsberg is lead; the quantity of lead is at most forty pounds in a quintal, or one hundred pounds of the ore. The lead worked off on a test or concave hearth yields about a hundred and ten grains of silver, and the silver contains only a three hundred and eighty-fourth part of gold; yet this little quantity of gold, amounting scarcely to a third of a grain in a hundred weight of the ore, is thus collected with profit. The author above mentioned confines this method of separation to such silver as is poor in gold, and reckons parting with aqua fortis more advantageous where the gold amounts to above a sixty-fourth of the silver: he advises also not to attempt concentrating the gold too far, as a portion of it will always be taken up again by the silver. Mr. Scheffer, however, relates (in the Swedish Memoirs for the year 1752), that he has by this method brought the gold to perfect fineness; and that he has likewise collected all the gold which the silver contained; the silver of the last operations, which had taken up a portion of the gold, being reserved to be worked over again with a fresh quantity of gold holding silver. The sulphurated silver is purified by continuing it in fusion for some time with a large surface exposed to the air; the sulphur gradually exhales, and leaves the silver entire.

**PARTING BY KEIR'S COMPOUND ACID.** See SILVER.

**PEARL ASH.** An impure alkali obtained by lixiviation from the ashes of plants. Mr. Kirwan\* examined the Dantzic pearl-ash. It is exceedingly white, and if not exposed to the air very hard. Its taste is alkaline. The contents of various specimens were different, but at a medium he found the pound troy to consist of

Fixed air	—	—	1290 grains
Moisture	—	—	414
Vitriolated tartar	—	—	505
Digestive salt and tartar	—	—	36
Earth	—	—	38
Alkali	—	—	3477
			<hr/>
			4760

As the examination of the alkalis of commerce must be of great utility to the manufacturer, but is very tedious in the way of solution and evaporation, Mr. Kirwan proposes a test by the precipitation of the earth from alum by solutions of these salts.

To discover whether any quantity of fixed alkali worth attention exists in any saline compound, dissolve one ounce of it in boiling water, and into this solution let fall a drop of the solution of corrosive sublimate. This will be converted into a brick colour if an alkali be present, or into a brick colour mixed with yellow if the substance contained lime.

But the substances used by bleachers being always impregnated by an alkali, the above trial is in general superfluous, except for the purpose of detecting

\* Irish Transactions 1789.

lime. The quantity of alkali is therefore what they should chiefly be solicitous to determine: and for this purpose,

1. Procure a quantity of alum, suppose one pound, reduce it to powder, wash it in cold water, and then put it into a tea-pot, pouring on it three or four times its weight of boiling water.

2. Weigh an ounce of the ash or alkaline substance to be tried, powder it, and put it into a Florence flask with one pound of pure water (common water boiled for a quarter of an hour, and afterwards filtered through paper, will answer) if the saline substance to be examined be of the nature of barilha or pot-ash, or half a pound of water if it contain but little earthy matter or pearl-ash. Let them boil for a quarter of an hour; when cool, let the solution be filtered into another Florence flask.

3. This being done, gradually pour this solution of alum hot into the alkaline solution also heated. A precipitation will immediately appear. Shake them well together, and let the effervescence, if any, cease before more of the aluminous solution be added. Continue the addition of the alum until the mixed liquor, when clear, turns syrup of violets, or paper tinged blue by radishes or by litmus, red. Then pour the liquor and precipitate on a paper filtre placed in a glass funnel, and the precipitated earth will remain on the filtre. Pour on this a pound or more of hot water gradually, until it becomes tasteless. Take up the filtre acid, and let the earth dry in it until they separate easily. Then put the earth into a cup of Staffordshire ware, place it on hot sand, and dry the earth until it no longer adheres either to glass or iron; then reduce it to powder in the cup with the glass pebble, and keep it a quarter of an hour in a heat from  $470^{\circ}$  to  $500^{\circ}$ .

4. The earth being thus dried, throw it into a Florence flask, and weigh it; then put about an ounce of spirit of salt into another flask, and place this in the same scale as the earth, and counterbalance both in the opposite scale: this being done, pour the spirit of salt gradually into the flask that contains the earth; and when all effervescence is over (if there be any) blow into the flask, and observe what weight must be added to the scale containing the flasks to restore the equilibrium; subtract this weight from that of the earth, the remainder is a weight exactly proportioned to the weight of mere alkali of that particular species which is contained in one ounce of the substance examined; all beside is superfluous matter.

Kirwan remarks that alkalies of the same species may thus be directly compared, because alkalies of different species cannot but require the intervention of another proportion; and the reason he gives is, because equal quantities of alkalies of different species precipitate unequal quantities of earth of alum. Thus 100 parts by weight of mere vegetable alkali precipitate 78 of earth of alum; but 100 parts of mineral alkali precipitate 170,8 parts of that earth. Therefore the precipitation of 78 parts of earth of alum by vegetable alkali, denotes as much of this as the precipitation of 170,8 of that earth by the mineral alkali denotes of the mineral alkali. Hence the quantities of alkali in all the different species of pot-ashes, pearl-ashes, weed or wood-ashes, may be immediately compared by the above test, as they all contain the vegetable alkali; and the different kinds of kelp or kelps manufactured in different places, and the different sorts of barilha, may be thus compared, because they all contain the mineral alkali; but kelps and pot-ashes, as they contain different sorts of alkali, can only be compared together by means of the proportion above indicated.

The application of this test is founded on the following principles:

1. That a hot solution of a free alkali, or of an alkali combined only with



fixed air or sulphur, can hold no terrene or metallico-neutral salt in solution; though it may alkalino-neutral salt or quicklime, if the alkali be free from fixed air.

2. That earth of alum cannot be precipitated either totally or partially by the hot solutions of any alkalino-neutral salts, and therefore that its precipitation is always due to the presence of a free alkali, or at least of an alkali combined only with fixed air or sulphur, to whose quantity it is always proportional. It is true, quick-lime will also decompose alum; but the presence of quick-lime is easily discovered by the addition of a few drops of any mild alkaline solution, and by the same means as easily separated.

3. That if the earth of alum takes up fixed air (which would increase its weight), this air will be separated by the heat employed in drying it, or at least by the spirit of salt poured upon it.

Kirwan says, he can see but one inaccuracy attending this test, and that of little moment; it is this, if the alkali contains sulphur, this will also be precipitated with the earth of alum, and increase its weight. The limits of this inaccuracy, at least in common cases, scarcely reach two or three grains, as we shall presently find.

Sulphur is easily detected in any alkaline solution, by saturating it with an acid; hepatic air is generally developed, and the liquor becomes troubled.

Not only the proportion, but also the absolute weight of alkali in different alkaline substances or ashes, may be found by this test. Attention must be paid to the nature of the alkali, and the quantity of earth; a determinate portion will throw down, which must be ascertained as to the first by experiment, and as to the latter by fundamental trials.

**PEARLS.** From the beauty, lustre and scarcity of this animal product, it has obtained a place among precious stones, though it possesses none of their hardness. It is a calculus or morbid concretion produced in a certain shell-fish of the oyster kind, and sometimes in common oysters and muscles. It is sometimes found upon the inside of the shell, and sometimes in the body of the animal.

The mother of pearl fish, or pearl oyster, is an inhabitant of the bottom of the sea, where it remains fixed, and is not to be had but by diving. A number of small ships is generally engaged together in this dangerous business, on such particular spots as have been found to be rich in the pearl fish, and at certain seasons of the year. The divers, according to Neumann, are let down by ropes, and immediately drawn up again upon their pulling a bell as a signal for that purpose. Machines have been contrived for enabling divers to remain some time at the bottom, with a supply of air, beneath a large vessel called the diving-bell, or by means of tubes; but it does not appear that they have been received into use in the pearl fishery. Suffocation is not, however, the only danger to which the divers are exposed. They are subject to ruptures of some of the vessels, from the vast pressure of the water at great depths, and to be wounded or devoured by fishes of prey, which some of the rich beds of pearl fish are so much infested with, that scarcely any one can venture down at all.

After the pearl oysters are thus got up, there still remains a process not a little prejudicial to the health, and extremely offensive. If the shells were opened directly by any violent means, the pearl, said to be at this time in a somewhat soft state, would be liable to be injured, and become of little value. The whole are therefore laid in heaps till the shells open spontaneously, and the fish putrefies: after which, the corrupted cadaverous matter is searched diligently for the

the pearls, which are often too few to pay the expence of the proprietor, much less to make any recompense to the workmen for a service so loathsome and so hazardous.

Pearls are generally divided into oriental and occidental, more from their qualities than the place of produce, the oriental being reckoned the best, as for the most part they are. The principal oriental pearl fisheries are in the Persian Gulph, and on the coasts of Persia and Arabia; near the islands of Ceylon, Manaar, Sumatra, Java, and Borneo; on some of the coasts of Japan; between Banana and Cochin; off Cape Comorin, and in other parts along the Malabar coast, as particularly at Tutticorin, where there is an excellent pearl bank in possession of the Dutch. The most remarkable pearl fisheries of America are in the gulph of Mexico, along the coast of New Spain; off St. Margarite or the Pearl Island; in the Rio de la Hacha, at the islands of St. Martha, Quibo, Gorgonia, &c. In Europe, pearls are occasionally found on the coasts of Scotland, Livonia, Courland, in the river Ilts in Bohemia, in the Regen in Bavaria, in certain lakes near Augsberg, and in various other places.

There are pearls of various colours, figures and magnitudes, of an exquisite silver-like brightness, semi-transparent, opaque, opal-coloured, yellow, greenish, blueish, grayish, reddish, brownish, blackish, rainbow-coloured; round, oval, conical, cylindrical, angular; from the size of a millet-seed or less, to that of a hazel-nut or more. It is observable, that the larger ones approach generally to the figure of a pear. The largest pearl hitherto known is described by Tavernier, in the possession of the king of Persia. It was bought by him at the fishery of Catifa in Arabia, for the sum of 32,000 tomans, or above 110,000*l.* sterling. It is in the shape of a pear, very regular, and without fault. The diameter, measured on the engraving in Tavernier's Travels, is 0.63 English inch at the largest part, and the length 1.3 inch. Another pearl, belonging to the Great Mogul, and perfectly round, mentioned by the same author as the largest in the world of that figure, measures 0.62 English inch in diameter. Neumann mentions a pearl he saw in the English crown, said to be worth 10,000*l.* sterling.

Pearls are valued for their roundness, their size, and their water, that is, their lustre and purity. Their weight is estimated in Europe by carats, in Persia by abas's, and in Golconda and Visapour by ratis, each abas and rati being one eighth part less than a carat. The weight of small pearls is expeditiously ascertained, by a brass instrument with holes of different sizes; so that the weight of a pearl is known from the hole it fits. Small irregular pearls are valued from the number that make up an ounce. Neumann gives the following rates: If an hundred makes an ounce, they are valued at one hundred rix-dollars; if the number be less, the price is greater; if the number be greater, the price is less. Two hundred to the ounce cost but seventy rix-dollars; three hundred, fifty; nine hundred, ten; two thousand, three; four thousand, two and a half. Of the very small sort, called seed pearls, used in medicine, an ounce usually contains eight or ten thousand, and costs, if the pearls are of the oriental kind, two rix-dollars; if occidental, one rix-dollar and twelve gros. The rix-dollar is four shillings and six-pence, and the gros about two-pence.

Attempts have been made to take out stains from pearls, and to render the foul opaque-coloured pearls equal in beauty to the oriental. Abundance of processes not to be depended on are found in books of receipts and travels. Pearls may be cleaned from external foulness by washing with a little Venice



soap and warm water, or ground rice and salt, with starch and powder blue, with plaster of Paris, with white coral, with white vitriol and tartar, with cuttle bone, pumice stone, and other similar substances. But it is not practicable to take out a stain which reaches deep into the substance of the pearl. Nor can a number of small pearls be united, as some pretend, into a mass similar to an entire natural one.

Successful attempts have nevertheless been made to form artificial compositions, so greatly resembling natural pearls, as not to be distinguished from natural pearls, except in their magnitude and apparent perfection. Reaumur has given a memoir on this subject in those of the French Academy for 1716. The ingredient for giving the colour is a fine, silver-like substance found upon the under-side of the scales of the blay or bleak-fish. The scales taken off in the usual manner, are washed and rubbed with fresh parcels of clean water, and the several liquors allowed to settle. The water being then poured off, the pearly matter remains at the bottom of the consistence of oil, called by the French *essence d'orient*. A little of this is dropped into a hollow bead of blueish glass, and shaken about so as to line the internal surface; after which, the cavity is filled with wax to give solidity and weight.

I do not know of any modern analysis of pearls. Neumann found, that neither water nor ardent spirit acts upon its powder. The mineral acids dissolve it, and from the vitriolic acid there separates a crystalline matter. Caustic alkali, whether volatile or fixed, did not act upon it; but, which is strange, the plain alkaline ley, or, as I take it, solution of mild alkali, corroded a little of the pearl into a flaky substance. Four drams of pearl distilled in a glass retort with an open fire gradually increased, gave over 14 grains of an empyreumatic alkaline fluid, with some vestiges of empyreumatic oil in the neck of the retort. The fixed residue was of an ash gray colour, and weighed three drams two scruples six grains. This being farther calcined in an open vessel, then elixated with water, filtered, and evaporated, afforded five grains of a fixed salt, which appeared of a fine white colour, had a warm and not very saline taste, effervesced with vitriolic acid, and during the effervescence discharged a little marine acid in vapour.

From these experiments, I conclude, that the pearl consists of much phosphorated lime, of which the phosphoric acid was disengaged by the treatment with vitriolic acid, and the lime formed selenite; some animal mucilage, which afforded the volatile alkali and oil in distillation; and a small portion of soda and marine salt found in the residue.

PEAT. Geanthrax. Kirwan remarks, that there are two substances called by this name. The first is of a brown, yellowish-brown, or black colour, found in moorish grounds in Scotland, Holland, Germany, and elsewhere. When newly cut it has a viscid consistence, but hardens by exposure to the air. It consists of clay mixed with calcareous earth and pyrites, and sometimes contains common salt. While soft it is formed into oblong pieces for fuel, after separation of the pyrites and stones. By distillation it affords water and oil, and volatile alkali, and a small proportion of fixed alkali is found in its ashes, which are either white or red according as they contain more or less ochre or pyrites.

The second kind is found near Newbury in Berkshire. It contains but little earth, but chiefly consists of wood, branches, twigs, roots of trees, with leaves, grass, straw, and weeds.

The substance called stone turf in England, appears to be of the nature of peat.

peat. It is soft in the earth, but soon afterwards hardens. From long exposure to the air it becomes pulverulent. Magellan informs us, that this pit turf is advantageously used by Mr. Wilkinfon, in his large smelting furnace for iron in Lancashire.

PECH-BLENDE, or PITCH-BLENDE. The celebrated professor Klaproth has detected a new metallic substance in the mineral usually distinguished by the name of pech-blende, or pitch-blende, and ranged among the ores of zinc. As it is not reducible but with the most extreme difficulty, and then only into minute grains, it appears of little consequence to enter into any formal description of its metallic state: for which reason, I shall here follow the order of the professor's analysis\*.

The pitch-blende, or ore of uranite, is found in masses, or else stratified with other earths or minerals, in the Swedish and Saxon mines. It consists of two varieties: the first in masses of a blackish colour, inclining to a deep steel gray, of little brilliancy; its fracture is unequal, and concave in the smallest parts. It is perfectly opaque, considerably hard, and becomes convertible into a black powder by trituration. Its mean specific gravity is about 7.5. The second variety is usually found in strata, and is distinguished from the former by a deeper black colour intermixed with spots of red; its colour is more shining, and approaches that of coal; it is less hard, and, when pulverized, it has a greenish tinge.

This mineral suffers no change before the blow-pipe. With mineral alkali it affords a spongy, semi-opaque, gray globule. With microcosmic salt it melts, and affords a green transparent globule; and in both there are sometimes seen small globules of reduced lead. When the mineral is treated alone, in a proper vessel, it gives out sulphureous acid and sulphur, with loss of weight; but if it be afterwards kept ignited for a considerable time beneath a muffle, it gains some weight by calcination.

The vitriolic acid acts very imperfectly upon pitch-blende; but nitrous acid completely decomposes it, holding most part in solution, while a small proportion of sulphur, and some siliceous earth, fall down. Marine acid acts but imperfectly upon it; but aqua regia dissolves it, as well as the pure nitrous acid. This solution, after it had deposited a small quantity of corneous lead, afforded large transparent crystals by repose in the cold, which were of a faint yellowish-green colour, and of a figure not easy to be ascertained.

It was remarkable, that this substance was not precipitable from its solvents either by iron or zinc; but volatile liver of sulphur threw down a brownish-yellow precipitate. Nut-galls did not precipitate any thing, unless the superabundant acid were neutralized by an alkali; and in this case, the precipitate by galls was of a chocolate brown.

A distinctive criterion of this metallic substance was, its brownish-red colour when separated by Prussian alkali; a circumstance indeed common also to copper: but this last metal falls down in flocks, whereas the former is uniformly separated through the whole fluid. Volatile alkali usually precipitates it of a yellow colour, more or less obscure, according to the purity of the mineral, or of the alkali. The two fixed alkalis, when pure, precipitate it completely in the form of a lemon-coloured calx. Mild alkalis afford a paler calx.

The yellow precipitate is very soluble in acids, and affords crystals by combination with the vitriolic and acetic acids. Phosphoric acid affords yellowish

\* Journal de Physique, April 1790.



irregular flocks, sparingly soluble in water. Alkalis do not dissolve the yellow matter either in the dry or humid way.

Various attempts were made by the discoverer to revive it to the reguline state. He triturated it with linseed oil to the consistence of a paste, burned the oil in a roasting test, then placed the remaining black powder in a crucible lined with charcoal, and well covered, and exposed it to a violent heat; which operated a reduction of manganese in another crucible, but produced no other change in the calx of uranite than to render it soluble in nitrous acid, with effervescence, heat, and escape of nitrous air. This altered calx was then put into an assayer's test, covered with borax, and mixed with charcoal, and the lid luted on. The heat of a porcelain furnace reduced it into a coherent mass, consisting of very small metallic globules agglutinated together.

**PELICAN.** A pelican is a glass alembic consisting of one piece. It has a tubulated capital, from which two opposite and crooked beaks pass out, and enter again at the belly of the cucurbit. This vessel has been contrived for a continued distillation and cohobation, which chemists call circulation. The volatile parts of substances put into this vessel rise into the capital, and are obliged to return through the crooked beaks into the cucurbit; and this without interruption, or luting or unluting the vessels.

Although the pelican seems to be a very convenient instrument, it is nevertheless little used, and even much neglected at present, either because the modern chemists have not so much patience as the ancient chemists had, for making long experiments; or because they find that two matrasses, the mouth of one of which is inserted into the mouth of the other, produce the same effect.

**PELLICLE.** By this word chemists mean a very thin saline crust, which is formed upon the surfaces of solutions of salts, when they are evaporated to a certain degree. This pellicle is nothing else than a number of saline particles crystallized by evaporation at the surface of the liquor, rather than any where else, because the evaporation is made there. These small crystals of salt at first cover the surface of the liquor, and give it a dusky appearance, as if it were covered with dust, or with a very thin skin, from which appearance the name of pellicle has been given.

As all crystallizable salts may be crystallized by evaporation alone, in the solution, therefore, of any of these salts a pellicle may be formed; and also, as all solutions of salts, evaporated till a pellicle is formed, furnish crystals by exposing the liquor to cold, chemists have established a general rule for crystallization, to evaporate solutions of salts till a pellicle is formed, and then to leave them to crystallize by exposure to cold.

This rule is applicable to many salts, but is not general; for some salts, as common salt, do not crystallize by exposure to cold, although the solution of them has been previously evaporated till a pellicle has been formed: while other salts, as nitre and Glauber's salt, may be crystallized in great quantities, although their solutions have not been evaporated so much as that a pellicle has been formed. Hence, to crystallize such salts as common salt, the evaporation must be continued after the pellicle has been formed; and to obtain fine crystals of nitre, Glauber's salt, and others which crystallize in a similar manner, the evaporation must not be continued till a pellicle is formed, but their solutions must be left to cool slowly before it has been so much evaporated. See **CRYSTALLIZATION.**

**PENNY.**

**PENNY-WEIGHTS**, are fictitious parts into which we suppose any mass of silver to be divided, to specify its degree of purity.

Any mass of silver, the purity of which is to be examined, is supposed to consist of twelve equal parts called penny-weights; and if the silver be perfectly fine, and contain no alloy, then the twelve parts of the mass are all of pure silver, and this silver is said to be silver of twelve penny-weights. If the mass of silver contain a twelfth part of alloy, it will then contain only eleven parts of pure silver, and it will be called silver of eleven penny-weights.

To express more precisely the value of silver, each penny-weight is subdivided into twenty-four grains.

A penny-weight in England is also a real weight used in the weighing of metals. It is equal to twenty-four real grains, and is the twentieth part of an ounce troy.

**PEPPER.** The black pepper of the East-Indies contains an essential oil, which has a strong and durable smell, and a taste the mildest of all essential oils. This oil is partly elevated in distillation by rectified spirit of wine, which thereby acquires the flavour but none of the pungency of the pepper. The spirituous extract is excessively fiery. The watery extract is also very hot and biting. Neither this menstruum nor the spirit can, singly, extract all the hot matter of the pepper.

Sixteen ounces of black pepper yielded with water ten ounces of gummy extract, and afterwards with rectified spirit three drams of resin; another pound, treated first with spirit, gave two ounces and two drams of resinous extract; afterwards with water, seven ounces four drams and two scruples of gummy matter. This last extract had still some degree of pungency, rectified spirit seeming not to take up all the active parts any more than water. Of essential oil, about two drams and a half may be obtained from a pound.

White pepper has the same kind of taste and flavour as the black, but in a much less degree. It agrees also with the black in the nature of its chemical principles; and is, in effect, the same kind of fruit, gathered before it is grown fully ripe, and freed from the outer skin. Neumann.

**PEPPER (JAMAICA), PIMENTO, or ALL-SPICE.** The pimento trees grow spontaneously, and in great abundance, in many parts of Jamaica, but more particularly on hilly situations near the sea, on the northern side of that island.

This tree is so entirely the child of nature, that not one attempt in fifty to propagate the young plants, or to raise them from the seeds, in parts of the country where it is not found growing spontaneously, have succeeded. The usual method of forming a new pimento plantation, which in Jamaica is called a walk, consists in appropriating a piece of wood land, in the neighbourhood of a plantation already existing, or in a country where the scattered trees are found in a native state, the woods of which being fallen, the trees are suffered to remain on the ground till they become rotten and perish. In about a year after the first season, abundance of young pimento plants will be found growing vigorously in all parts of the land, which are doubtless produced from ripe berries scattered there by the birds. At the end of two years it will be proper to cleanse the land thoroughly, leaving such only of the pimento trees as have a good appearance. These will then soon form groves, which perhaps do not require much attention after the first four or five years.

It does not appear that in all the vegetable creation there is a tree of greater beauty



beauty than a young pimento. The trunk, which is of a gray colour, smooth and shining, and entirely free from bark, rises to the height of fifteen or twenty feet. It then branches out on all sides, richly clothed with leaves of a deep green, which, in the months of July and August, are beautifully relieved by an exuberance of white flowers. These leaves are equally fragrant with the fruit; and, in distillation, yield an odoriferous oil, which, Edwards informs us, is very commonly used in the medicinal dispensaries of Europe for oil of cloves.

The berries become fit for gathering soon after the trees are in blossom; for the fruit is not suffered to ripen on the tree, because the pulp in that state is difficult to cure. It is, however, impossible to prevent some of the ripe berries from mixing with the rest; but if the proportion of them be great, the price of the commodity is considerably injured.

It is gathered by the hand; and one labourer, on the tree, employed in gathering the small branches, will give employment to three below (who are generally women and children) in picking the berries. An industrious picker likewise will fill a bag of 70lb. in the day. It is then spread on a terrace, and exposed to the sun for about seven days; in the course of which it loses its green colour, and becomes of a reddish brown, and when perfectly dry it is fit for market.

In a favourable season, a single pimento tree has been known to yield 150lbs. of the raw fruit, or one cwt. of the dried spice: for there is generally a loss of one-third in curing. A plentiful crop, however, occurs perhaps but once in five years; and the price in the British market fluctuates accordingly. Its average for some years past may be put at 10d. the pound, including the duty, which is 3d.

This, though certainly a much greater price than the commodity bore in former years, gives so little profit to the owner, compared with that of some other productions, that the growth of pimento decreases every year, many beautiful walks being daily cut down, and the land appropriated to the cultivation of sugar. Its annual export from Jamaica (the only one of the British colonies that produces pimento) is about 6000 bags of 112lbs. each.

Neumann says, that pimento appears from a chemical examination to contain: 1. An indissoluble earth, exceeding in quantity all the other principles taken together, and amounting to five drams and a scruple in an ounce. 2. Gummy or mucilaginous matter, which is the ingredient next in quantity. An ounce treated with water at first gave two drams and two grains of gummy extract; and another ounce, freed by rectified spirit from all that the menstruum could dissolve, yielded still with water five scruples of mucilage. 3. A resinous substance in smaller quantity. The resinous extract obtained by applying rectified spirit at first, amounted to only one dram and six grains from an ounce; an ounce freed from its mucilaginous matter by coction in water, yielded of pure resin no more than one scruple. 4. An essential oil in still smaller quantity: of this principle an ounce of pepper contains scarcely half a dram.

Upon examining the qualities of the several products, it appeared, that the oil is the principal and characteristic part, containing all the smell and the aromatic flavour, though not the pungency of the berry. As the prevailing flavour of pimento approaches that of cloves, the oil also greatly resembles the genuine oil of cloves. It has the same kind of smell and taste, discovers no great heat or pungency, and is so heavy as to sink in water; to which may be added, that the oil of pimento, like that of cloves, resides chiefly in the shell, or cortical part, the internal substance yielding little or none. 2. That the heat and pungency are

are lodged in the resin. In this respect also pimento agrees with cloves; but as pimento in substance is far less hot and fiery than cloves, its resin is also more mild. 3. That the gummy parts have very little activity.

Rectified spirit of wine elevates nothing from this spice in distillation, the oil of pimento being too ponderous to rise with so light a fluid. The only way of making a spirit from it is to dissolve some of the oil in pure spirit of wine. An agreeable spirituous water may be made with proof spirit, the watery phlegm in that liquor carrying up a part of the oil.

PERIDOT. The CHRYSOLITE, which see.

PERIGORD STONE. An ore of manganese, black, heavy, of a glittering appearance when broke, and in the whole resembling a slag from a smith's forge.

PERUVIAN BARK. The *cinchona officinalis* Lin. which furnishes this bark, is generally about fifteen feet high and six inches thick, somewhat resembles our cherry-tree, grows promiscuously in forests, particularly in the hilly parts of Quito in Peru, and is spontaneously propagated from its seeds.

The bark has some odour, to most people not unpleasant; and very perceptible in the distilled water, in which floating globules, like essential oil, have been observed. Its taste is bitter and astringent, accompanied with a degree of pungency, and leaving a considerable lasting impression on the tongue.

Two species are mentioned, viz. the coloured and the white. The coloured includes the pale, the red, the yellow, and the knotty; their bark being coloured, having the cinchona taste and smell, and the trees having very smooth leaves and purplish flowers. The white includes four varieties, their bark being of a whitish colour, with very little taste or smell: the trees have broad hairy leaves, and very fragrant flowers with hairs on the inside.

The proper red bark and one of the white kind have been found in the province of Santa Fé.

The *cinchona Caribbæa* Lin. *cinchona Jamaicensis*, Phil. Trans. vol. lxxvii. p. 11. is called the sea-side beech in Jamaica, and grows from 20 to 40 feet high. The white, furrowed, thick outer bark is not used; the dark-brown inner bark has the common flavour, with a mixed kind of taste, at first of horse-radish and ginger, becoming at last bitter and astringent. It seems to give more extractive matter than the *cinchona officinalis*. Some of it was imported from St. Lucia, in consequence of its having been used with advantage in the army and navy during the last war. The fresh bark is found to be considerably emetic and cathartic, which properties it is said to lose on drying.

The pale and the red are chiefly in use. The pale is brought to us in pieces of different sizes, either flat or quilled, and the powder is rather paler than that of cinnamon. The red is generally in much larger, thicker, flattish pieces, but sometimes also in form of quills, and its powder is reddish, like that of Armenian bole. It is much more resinous, and possesses the sensible qualities of the cinchona in a much higher degree than the other sorts; and the more nearly these resemble the red bark, the better they are now considered. The red bark is heavy, firm, sound, and dry; friable betwixt the teeth; does not separate into fibres, and breaks, not shivery, but short, close, and smooth. It has three layers: the outer is thin, rugged, of a reddish-brown colour, but frequently covered with mossy matter: the middle is thicker, more compact, darker coloured, very resinous, brittle, and yields first to the pestle: the inmost is more woody, fibrous, and of a brighter red.



The Peruvian bark yields its virtues both to cold and boiling water; but the decoction is thicker, gives out its taste more readily, and forms an ink with a chalybeate more suddenly than the fresh cold infusion. This infusion however contains at least as much extractive matter, but more in a state of solution; and its colour, on standing some time with the chalybeate, becomes darker, while that of the decoction becomes more faint. When they are of a certain age, the addition of a chalybeate renders them green; and when this is the case, they are found to be in a state of fermentation, and effete. Mild or caustic alkalis or lime precipitate the extractive matter, which in the case of the caustic alkali is re-dissolved by a farther addition of the alkali. Lime-water precipitates less from a fresh infusion than from a fresh decoction; and in the precipitate of this last, some mild earth is perceptible. The infusion is by age reduced to the same state with the fresh decoction; and then they deposit nearly an equal quantity of mild earth and extractive matter; so that lime-water, as well as a chalybeate, may be used as a test of the relative strength and perishable nature of the different preparations, and of different barks. Accordingly cold infusions are found by experiments to be less perishable than decoctions; infusions and decoctions of the red bark, than those of the pale; those of the red bark, however, are found by length of time to separate more mild earth with the lime-water, and more extracted matter. Lime-water, as precipitating the extracted matter, appears an equally improper and disagreeable menstruum.

**PETRIFICATIONS.** Stony matters deposited either in the way of incrustation, or within the cavities of organized substances, are called petrifications. Calcareous earth being universally diffused and capable of solution in water, either alone, or by the medium of fixed air or vitriolic acid, which are likewise very abundant, is deposited whenever the water or the acid becomes dissipated. In this way we have incrustations of lime-stone or of selenite in the form of stalactites or drop-stones from the roofs of caverns and in various other situations. This simple principle of chemical deposition, operating under different circumstances, will account for a great number of striking appearances observed in the bowels of the earth. In our small and hasty experiments, a speedy and copious solution of matter is required, and we do not scruple to declare that substance insoluble which requires one or two thousand times its weight of a fluid to dissolve and suspend it. But in the extensive and long continued operations of nature, a much less solubility will be sufficient to produce very marked effects. Hence, we may without difficulty account for the filiceous stalactites, mentioned by Chaptal, as well as the crystallised depositions of metallic bodies by us taken to be insoluble.

Systematical writers more particularly confine the term petrification to such organic substances as have been converted into stone, or have assumed the nature of a fossil. Much labour and erudition have been employed in giving denominations from the Greek to these, according to their apparent origin. It is perhaps difficult to shew the utility of such extended catalogues. At all events less will suffice the chemist.

The most remarkable observations relative to petrifications are thus given by Kirwan:

1<sup>st</sup>. That those of shells are found on or near the surface of the earth; those of fish deeper, and those of wood deepest. Shells in specie are found in immense quantities at considerable depths.

2<sup>dly</sup>.

2dly. That those organic substances that resist putrefaction most, are frequently found petrified: such as shells and the harder species of woods; on the contrary, those that are aptest to putrefy are rarely found petrified, as fish, and the softer parts of animals, &c.

3dly. That they are most commonly found in strata of marl, chalk, limestone, or clay, seldom in sand-stone, still more rarely in gypsum, but never in gneiss, granite, basalt, or shoerl; but they sometimes occur among pyrites, and ores of iron, copper, and silver, and almost always consist of that species of earth, stone, or other mineral that surrounds them, sometimes of flint, agate, or carnelian.

4thly. That they are found in climates where their originals could not have existed.

5thly. That those found in slate or clay are compressed and flattened. The arrangement of petrifications by Cronstedt is made under four heads, earthy, saline, inflammable, and metallic.

Calcareous petrifications are: 1. Chalk in the form of vegetables or animals, either loose or friable, or 2. Filled with solid lime-stone.

Siliceous petrifications are of the nature of flint or agate. Carnelians have been found in the form of shells, at the river Tomm in Siberia; agate in the form of wood; corraloids (millepora) of white flint; and wood of yellow flint.

This last is the produce of Italy, Adrianople, and Loughneagh a lake in Ireland. It is used to sharpen razors.

Argillaceous petrifications have been observed in the form of the roots of trees. The osteocolla is of this kind.

Saline petrifications are extraneous bodies penetrated by mineral salts. Human bodies have been twice found in the mine at Falun in Dalarne. The last was kept several years in a glass case, but began at length to moulder and fall to pieces. The turf and roots of trees, which are found in water strongly impregnated with vitriol, are considerably changed in their nature. They do not burn with a flame, but only like a coal in a strong fire, neither do they decay in the air.

Extraneous bodies penetrated by mineral inflammable matter appear to be of the nature of pit-coal. Of this kind is jet. See that article. Vegetables are found penetrated with asphaltum in a state of less preservation than jet. The compound of sulphur and iron, or martial pyrites, is likewise the agent of petrifications. Of these Cronstedt mentions human, bivalves, univalves, and insects, but gives no particulars of their history.

Metallic petrifications are: 1. Of silver, either native on the surfaces of shells in England, or mineralized with copper and sulphur in the fahlertz or gray silver ore, in form of ears of corn, &c. and supposed to be vegetables. These are found in argillaceous slate at Frankenburg, and Tahlitteran in Hesse. 2. Of copper, which is either in the form of calx, or mineralized. The calx of copper is deposited in the parts of animals. The turquoise stone, see page 560, is supposed to be ivory, or other bones of animals, which have undergone this change. Mineralized copper, or the cupreous pyrites, penetrates shells, and is also found in the form of fish in various parts of Germany.

The ferruginous petrifications likewise consist of iron, either in the form of a calx, which has assumed the place or shape of extraneous bodies (this consists chiefly of vegetables in the form of ochre or hematites); or else the martial pyrites, which has operated as the agent of petrification.



**PETROLEUM.** Petrol, Bergoel, Steinoel. Doctor Priestley has shewn in the third volume of his *Observations and Experiments on Air*, that essential oils, long exposed to the atmosphere, absorb not only the pure part, but also the phlogisticated part of it; an absorption, which must in time produce considerable changes in them. By a process of this sort naphtha is converted into petrol, which is an oil of various degrees of density, according to the time during which it has been exposed to the atmosphere; its colour is reddish, or yellow, brown, greenish, or blackish; it is found trickling from rocks, or issuing from the earth in the Duchy of Modena, and in various parts of France, Switzerland, Germany, and Scotland, as well as in Asia; also on the surface of the water of different fountains, or mixed with earth or sand, from which it is separated by infusion in water; the thinnest sort possesses the properties of naphtha, though in a lesser degree. It is rendered finer by distillation with water, and leaves a resinous residuum, and if distilled with a volatile alkali, the alkali acquires the properties of succinated ammoniac: and hence contains the acid of amber. Some sorts of it, according to Monnet, are nearly of the density of nut oil. It is insoluble in spirit of wine. Kirwan.

Mr. Fabroni of Florence has discovered that petroleum rectified several times is a good solvent of the elastic resin, and does not at all change its properties.

**PETUNTSE.** See PORCELAIN, also KAOLIN.

**PEWTER**, which is commonly called étain in France, and generally confounded there with true tin, is a compound metal, whose basis is tin. The best sort consists of tin allayed with about a twentieth, or less, of copper or other metallic bodies, as the experience of the workmen has shewn to be the most conducive to the improvement of its hardness and colour, such as lead, zinc, bismuth, and the metallic or reguline part of antimony. There are three sorts of pewter, distinguished by the names of plate, trifle, and ley-pewter. The first is used for plates and dishes; the second for the pints, quarts, and other measures of beer; and the ley-pewter is used for wine measures and large vessels.

The best sort of pewter consists of 17 parts of regulus of antimony to 100 parts of tin; but the French add a little copper to this kind of tin. A very fine silver-looking metal is composed of 100 pounds of tin, eight of regulus of antimony, one of bismuth, and four of copper. On the contrary, the ley-pewter, by comparing its specific gravity with those of the mixtures of tin and lead, must contain more than a fifth part of its weight of lead. This quantity of lead is far too much, considering some of the uses this sort of pewter is applied to; for acid wines will readily corrode the lead of the flagons, in which they are measured, into sugar of lead; which being taken internally, is productive of various chronic diseases, as the colica pictonum, palsies, stupors in the limbs, &c.

Foreigners generally assert, that English tin is always a mixed metal when exported abroad: and the French encyclopedists in particular (article ETAIN) inform us, on the authority of M. Rouelle, that the English tin, when cast into moulds of six inches in thickness, and cooled, if it be divided into three layers, the uppermost has three pounds of copper on the 100 of tin: the second layer has five pounds of lead to the same quantity of tin; and the lowest layer has nine of lead to the 100 of tin. Geoffroy had formerly given a similar account of the English tin, with some variety in the doses. But there never was any other foundation for such an assertion, than that pewter has been mistaken for tin abroad: and in fact, all pewter dishes, and all other pewter-pieces are called by the name of tin ware all over Europe, except in England. Nor could there  
ever

ever be any advantageous motive to hinder the export of pure tin from England, where it is found in a greater abundance than any where else. Besides the above, neither Borlase, nor Pryce, who wrote so minutely on the method of preparing tin in Cornwall, mentions any operation or mixtures this metal undergoes or receives, before or after it is cast in the slabs, blocks, or pieces of tin, in which size and form it is sold, and sent to every market in Europe; so that the whole must be a mistake in terms, as already mentioned, by taking pewter simply for tin.

**PHLEGM.** Chemists have given the name phlegm to the most watery part obtained from bodies by distillation or otherwise. It is now little used.

Phlegm is frequently water mixed superabundantly, and not combined in the bodies from which it is obtained. Such are the phlegms obtained by distillation with the heat of a water-bath, from all those vegetable and animal matters which contain no principle so volatile as to rise with a less heat than that of boiling water. These phlegms, which are produced merely by drying, are nothing but water almost pure, that is, the water of vegetation: but a phlegm consisting of water which had been combined in any body, as for instance, the phlegm obtained in the distillation of oils, is far from being pure water. It is still mixed and even united with a sensible quantity of the principles of the body, and requires further operations, and chiefly the assistance of intermediate substances, to separate it perfectly.

Neither is that phlegm pure water, which, though it is superabundant, yet adheres to certain substances, especially to those that are volatile. Such are liquid volatile alkalis, and most alkalis. By distillation we may separate a considerable quantity of their phlegm or superabundant water, which operation is called dephlegmation: but this phlegm contains always a certain quantity of the saline matters with which it was originally mixed.

Hence we may see that the word phlegm signifies in general the most watery part separated from several bodies, but that is rarely pure water; and that phlegms differ from each other according to the nature of the substances from which they are obtained.

**PHLOGISTON.** The whole of physical science consists in the arrangement or classification of facts. Investigation or analysis in chemistry is employed merely in discovering general results under which particular facts may be arranged, or to which they may be referred, notwithstanding the obscurity or disguise produced by individual circumstances, not essential to the phenomenon under investigation. Thus we may remark in the considerably simple motions of the heavenly bodies, that the moon revolves round the earth; but the situation of our planet renders the revolutions of the other planets round the sun less obvious. Investigation from optical principles, however, proved this to be the case, and it became a considerable advance in astronomy, that the motions of all the planets could be arranged under the fact of the moon's revolution considered as a general result. In this state of knowledge it became an object of research to ascertain what general fact these motions might be referred to. Des Cartes referred them to the motion of a floating body carried round by a vortex or whirling current of water. It was afterwards ascertained from the more general facts of bodies in motion, that the revolutions of the planets and those of floating bodies are by no means of the same kind. Newton \* was accidentally led to consider the path of bodies projected near the surface of the earth; and he found by accurate examination, that

\* See Voltaire's Elements of the Newtonian Philosophy.



the moon is a projectile kept from falling by a force impressed on it, in the same manner as a stone is made to describe a curve through the air, which last only wants a sufficient impulse to carry it round the earth in an orbit. Here then we see a general fact of another and more remote kind. Copernicus generalized the celestial motions, by merely referring them to the moon's motion. Newton generalized them still more, by referring this last to the motion of a stone through the air. And yet farther, this motion of the stone was shewn to be referable to two simple facts, namely, the uniform motion of a body acted on by a past impulse, and the accelerated motion of a body constantly acted upon by gravitation, or the cause of weight. Thus far Astronomers have proceeded in this department of science, and at this point they are at a stand; because no facts more simple have yet been remarked, under which the communication of motion either by impulse or gravitation can be classed.

From this familiar elucidation of the progress of astronomical science, which is very simple, it may easily be seen how great the probability is, that error may arise from classing facts under others of a different nature, and that when a combination of truth and falsehood is exhibited, as the means of explaining natural phenomena, the former may be made to support and maintain the latter, as was the case with the system of Copernicus united with the vortices of Des Cartes. It may also be remarked, that the false results, which from time to time are incorporated with the materials of any branch of philosophy, owe their establishment to superficial views, and the apparent or partial resemblance which seduces the cultivators of infant science: and that they generally maintain their ground until some very considerable addition is made to the general mass of information.

Without pretending to enter the wide field of chemical history, we may in a few words observe, that, from the nature of things, the first chemical operations must have consisted in the effects of heat applied to bodies in the operations of cookery, of pottery, and of mine works, which accordingly have existed, at least, as early as history itself. The operations in the humid way with saline substances appear to have been of much later date. And those upon bodies in the aeriform state are still more modern. These three classes of operations comprehend the whole of chemistry, and would naturally lead us to consider the subject of phlogiston, as it is supposed to exhibit itself in the dry, the humid, and the aeriform processes: but these processes are so frequently combined together, that it is scarcely possible to treat of them separately.

When bodies are heated to such a degree as to emit light, there are some which if left to themselves in the open air become cold again without any perceptible change in their properties; and there are others which retain their ignition, and even become hotter until an entire decomposition of the whole substance has taken place. This process is well known by the name of combustion or burning, and the distinction of bodies into combustible and incombustible is one of the most striking and distinct of any we are acquainted with. That a combustible body must have something in its properties or component parts not to be found in an incombustible body is evident. But it is not always easy to distinguish the existence of a property from that of a component part. For any thing we know on this obscure subject, two bodies may agree in certain properties and differ in others; whence it may follow, that bodies may agree in the property of combustibility, and yet possess no common principle or component part. It was nevertheless a habit of reasoning, much indulged in the middle ages, to refer effects rather to distinct substances than to habitudes or properties. The ancient chemists

chemists did not therefore so much endeavour to explain combustibility as a property, as to ascertain what might be the principle of combustibility in bodies. They looked round for general facts. Their attention became fixed on such bodies as are the most eminently combustible. They supposed these bodies to exist in various proportions in other bodies capable of being burned. In this way the science of chemistry came to be filled with accounts of the oils and sulphurs of bodies. But as it was not found practicable to exhibit these oils or sulphurs, a distinction was consequently made between the gross oils and sulphurs, and the more subtle or philosophical matters of the same denomination, which were supposed to give inflammability to bodies. As this refinement was carried farther, the denominations themselves were dismissed; and by the perspicuous modifications of Becher and Stahl, a common principle of inflammability, identical, and always similar to itself, capable of being extricated from bodies, and transferrable from one body to another in certain circumstances, was universally admitted by chemists under the denomination of phlogiston. The nature of the phlogiston was to be investigated from the facts. The most striking fact is, that the temperature of bodies becomes raised in those circumstances where the phlogiston is said to be extricated. The phlogiston was therefore considered to be elementary fire, existing as one of the principles of combustible bodies, deprived of its most eminent property while in this state of combination, but exhibiting all its distinctive attributes at the instant of disengagement.

The doctrine of heat, though of such extensive importance in almost every natural change, continued long in an unimproved state, because the facts are in general simple, and not easily analysed and referred to facts still simpler. Yet the moderns in their reflections on this subject could not but perceive that the temperature of bodies, and consequently the matter of heat, if such a thing exists, distributes itself with a sort of equality, as well through incombustible as combustible bodies. While the various capacities of bodies were unknown, the disposition of heat to enter into all bodies must have appeared to be absolutely equal. It was not easy to reconcile this with Stahl's doctrine of phlogiston or fixed fire. Again, this doctrine overlooks the necessity of respirable air in the process of combustion. The modern chemists were obliged to make considerable alterations, and those who maintained the phlogiston are at present returned to the old doctrine of sulphur and oils, though in more general terms. With them the phlogiston is not fixed fire, but some identical substance, the property of which is to be combustible, viz. to unite with respirable air, when at a certain temperature, and to produce, extricate, or develop heat. But what this substance may be is matter of discussion. For a time it was supposed, according to the hypothesis of Kirwan, to be inflammable air in a combined state. But it has not been possible to extricate inflammable air from the metals, excepting when water was present, of which this air is taken to be a component part. This doctrine is little insisted upon at present, and as far as authority may be considered of any value, it is destitute; for Kirwan has abandoned the phlogiston altogether.

Since the doctrine of phlogiston is tacitly established upon the position that a common principle of combustibility is necessary for the explanation of the facts; and as this position is assumed but not proved, we shall gain another different view of the subject by rejecting it, and substituting the property of rapidly combining with respirable air. This is simply the doctrine of the modern, or anti-phlogistian chemists. There is no inconsistency in affirming, that bodies may be strongly disposed to inflammability, and yet differ in every other property. Let



us then say, they reject as mere supposition, the notion that they do agree in any other respect than such as may be indicated by positive facts. The facts of combustion are simply, that respirable air is absorbed and enters into combination, while heat is given out. Elastic fluids are known to contain more heat in that state than when condensed. Much heat must therefore arise from the condensation of the vital air. It does not necessarily follow, that any heat came from the combustible body, or at least not more than might have been extricated under an equal change of circumstances from an incombustible body. Whence it follows, that the simple explanation of combustion from the facts is, that the combustible body has a strong attraction for vital air, at a certain temperature, that it has attracted this fluid, with the production of heat during the combination, and that its properties are changed. See HEAT.

In two theories, which differ so widely as that the one subtracts where the other adds, it must be a material, though not a decisive, point to ascertain whether the body under consideration becomes heavier or lighter by being burned. In this respect the antiphlogistian theory has the advantage; for, in all experiments which have yet been accurately made, bodies gain weight by being burned. If the residues of combustion were in all cases fixed, it would be easy to ascertain this general fact. But in all organised substances, and many among those of the mineral kingdom, most of the products assume the vaporous or elastic state. When the vapour is condensable, it is easier to ascertain its weight than when it continues elastic. There are many difficulties, however, which attend the accurate accomplishment of experiments, wherein a known supply of vital air is required to be given to the combustible matter, and the products are to be received, condensed, measured, or weighed. A notion of these difficulties may be had by consulting the writings of Lavoisier \*. This chemist found, by burning ardent spirit in a lamp with a serpentine chimney kept cool upon the principle of the worm of a still, nearly 17 ounces of water were collected from 16 of the spirit, and it is known that a considerable product of fixed air must also have been lost.

The metals which are truly combustible bodies, though few of them will burn in the common air of the atmosphere, without the assistance of foreign heat, exhibit this increase of weight in a remarkable manner. The general facts are, as I find them ready enumerated by Fourcroy in his notes on Kirwan's phlogiston, 1. There is no elastic fluid which is capable of calcining the metals but vital air. 2. They are not calcined by atmospheric air, but in proportion to the quantity of vital air it contains. 3. In proportion as they burn, they absorb, condense, and fix this vital air, which proves, as he infers, that the latter abandons that which held it fused, or divided in the state of an elastic fluid. 4. Hence he adds, that it is only the solid part of vital air which unites to metals. 5. And for this reason it is that rapid combustion is attended with a disengagement of heat and light. 6. But as the heat and light are bodies of such levity, that their weight cannot be appreciated by our instruments, the loss and disengagement of these, which he supposes to be principles, make no change in the weights of our experiments. 7. Metals therefore increase in weight by the quantity of vital air they fix during their combustion. 8. All the semi-metals, and imperfect metals, present absolutely the same phenomena, and are therefore facts of the same kind. 9. In all the various processes by which metals are calcined, otherwise than by

\* Elements of Chemistry. Memoirs of the Academy of Sciences. Journal de Physique.

means

means of the air, they undergo absolutely the same modification, their weight increases, and they lose their metallic state in the same manner as by the simultaneous action of heat and the air. Mr. Fourcroy calls these positive and simple facts, though indeed they include the consideration of the materiality of heat, which may perhaps be no more a separate matter than the phlogiston.

He afterwards adds the following observations: 1. That the metals differ in the several quantities of vital air they require for their saturation. 2. That some lose this principle by the simple contact of heat and light, sometimes even by the action of the latter only assisted by very little heat. 3. That the greater number do not admit of this, and are not therefore reducible by these agents. 4. That no induction can be made from this difference in the metallic calces, any more than it could be fairly concluded that neutral vitriolic salts do not contain the same acid as the metallic vitriols, because the latter are decomposable by mere heat, and the former not. 5. That not only the vital air is absorbed in different doses, but that it is likewise combined in them, after privation of a greater or less quantity of the matter of heat, and of light; and that the capacities of the residues or calces for heat will differ accordingly. 6. That each metallic calx may exist in different states of calcination from the absorption of the smallest quantity possible of vital air unto that which is necessary for saturating the metal; so that the calcination of each metal stops, as it were, at different degrees. Thus it is that lead becomes calcined, first of a gray, and then of a yellow and red colour, and iron is black and brown. 7. That the periods of calcination in each metal depend on circumstances which are more or less favourable to the attraction of the metals for vital air; the principal of which circumstances is a certain temperature, neither too high nor too low. Thus a certain metal will absorb and fix only a very small quantity of the vital air of the atmosphere, and never becomes any thing but a calx of a certain nature, at the usual temperature, whereas it will fix a much greater quantity, and its calcination will become complete, if it be strongly heated; such are zinc, iron, &c. 8. That the different metallic substances differ in their attractions for the basis of vital air, part of which attractions have been already ascertained as to their order, by Bergman, who, according to the system of phlogiston, remarked that the precipitation of metals in acids by each other, follows the same order in all acids, and must therefore depend much more on their disposition to become calcined, than on their respective attractions for the acid solvent. 9. Lastly, the metallic calces are decomposed and reduced to the metallic state by the laws of attraction followed by the vital air. Thus heat separates it from some, one metal takes it from another, inflammable air takes it from most metals, and carbone, or pure charcoal, perhaps from all.

Among the few metals which are capable of calcination and reduction by mere heat, there is no one which sets the theory of that process, and the doctrine of the antiphlogistians, in so clear a point of view as mercury. Lavoisier gives a very perspicuous account of the experiment\*, which can only be performed on a small scale.

He took a matrafs of about 36 cubical inches capacity, having a long neck of six or seven lines internal diameter, which was bended first sideways like that of a retort, and then in a reverse direction upwards, so as conveniently to be inserted beneath an inverted jar of mercury for pneumatic experiments. Into this matrafs was introduced four ounces of mercury, and a portion of the air was

\* Elements of Chemistry. The remarks, as well as the account of the experiment, are Lavoisier's.



then drawn out of the receiver by means of a syphon, and the station of the mercury noted in this vessel by pasting a slip of paper on its external surface. Having accurately noted the height of the thermometer and barometer, he lighted a fire in a furnace, which he kept up almost continually for twelve days, so as to keep the quicksilver always very near its boiling point. Nothing remarkable took place during the first day; the mercury, though not boiling, was continually evaporating, and covered the interior surface of the vessel with small drops, at first very minute, which gradually augmenting to a sufficient size, fell back into the mass at the bottom of the vessel. On the second day small red particles began to appear on the surface of the mercury: these, during the four or five following days, gradually increased in size and number, after which they ceased to increase in either respect. At the end of twelve days, seeing that the calcination of the mercury did not at all increase, he extinguished the fire, and allowed the vessels to cool. The bulk of air in the body and neck of the matras, and in the bell-glass, reduced to a medium of 28 inches of the barometer, and  $54.5^{\circ}$  of the thermometer, at the commencement of the experiment was about 50 cubical inches. At the end of the experiment the remaining air reduced to the same medium, pressure and temperature, was only between 42 and 43 cubical inches; consequently it had lost about one-sixth of its bulk. Afterwards, having collected all the red particles, formed during the experiment, from the running mercury in which they floated, he found these to amount to 45 grains.

Mr. Lavoisier was obliged to repeat this experiment several times, as it is difficult in one experiment both to preserve the whole air upon which we operate, and to collect the whole of the red particles or calx of mercury, which is formed during the calcination.

The air which remained after the calcination of the mercury in this experiment, and which was reduced to five-sixths of its former bulk, was no longer fit either for respiration or for combustion; animals being introduced into it were suffocated in a few seconds, and when a taper was plunged into it, it was extinguished as if it had been immersed in water.

In the next place, he took 45 grains of the red matter formed during this experiment, which he put into a small glass retort, having a proper apparatus for receiving such liquid, or gaseous product, as might be extracted: having applied a fire to the retort in the furnace, he observed that in proportion as the red matter became heated, the intensity of its colour augmented. When the retort was almost red-hot, the red matter began gradually to decrease in bulk, and in a few minutes after it disappeared altogether; at the same time  $41\frac{1}{2}$  grains of running mercury were collected in the recipient, and seven or eight cubical inches of elastic fluid, greatly more capable of supporting both respiration and combustion than atmospheric air, were collected in the pneumatic apparatus.

A part of this air being put into a glass tube of about an inch diameter, shewed the following properties: A taper burned in it with dazzling splendour, and charcoal instead of consuming quickly, as it does in common air, burnt with a flame, and attended with a decrepitating noise, like phosphorus, and threw out such a brilliant light that the eyes could hardly endure it. This is the air to which Dr. Priestley gave the name of dephlogisticated air. See AIR ATMOSPHERICAL, AIR VITAL.

In reflecting upon the circumstances of this experiment we readily perceive, that the mercury, during its calcination, absorbs the salubrious and respirable part of the air, or, to speak more strictly, the base of this respirable part; that  
the

the remaining part is a species of mephitic, incapable of supporting combustion or respiration; and consequently that atmospheric air is composed of two elastic fluids of different and opposite qualities. As a proof of this important truth, if we recombine these two elastic fluids, which we have separately obtained in the above experiment, viz. the 42 cubical inches of mephitic, with the eight cubical inches of respirable air, we reproduce an air precisely similar to that of the atmosphere, and possessing nearly the same power of supporting combustion and respiration, and of contributing to the calcination of metals. See IRON.

Although this experiment furnishes us with a very simple means of obtaining the two principal elastic fluids which compose our atmosphere separate from each other, yet it does not give us an exact idea of the proportion in which these two enter into its composition: for the attraction of mercury to the respirable part of the air, or rather to its base, is not sufficiently strong to overcome all the circumstances which oppose this union. These obstacles are the mutual adhesion of the two constituent parts of the atmosphere for each other, and the elective attraction which unites the base of vital air with caloric: in consequence of these, when the calcination ends, or is at least carried as far as is possible, in a determinate quantity of atmospheric air, there still remains a portion of respirable air united to the mephitic, which the mercury cannot separate. It is ascertained from other experiments, that, at least in our climate, the atmospheric air is composed of respirable and mephitic airs, in the proportion of 27 and 73.

Since, during the calcination of mercury, air is decomposed, and the base of its respirable part is fixed and combined with the mercury, it follows from the general facts relating to combustion, that heat and light must be disengaged during the process. But the two following causes prevent us from being sensible of this taking place, as the calcination lasts during several days, the disengagement of heat and light spread out in a considerable space of time, becomes extremely small for each particular moment of the time, so as not to be perceptible, and the operation being carried on by means of fire in a furnace, the heat produced by the calcination itself becomes confounded with that proceeding from the furnace. To this might be added, that respirable part of the air, or rather its base, in entering into combination with the mercury, does not part with all the heat which it contained, but still retains a part of it in the new compound; but the discussion of this point, and its proofs from experiment, do not belong to this part of our subject.

The disengagement of heat and light is rendered apparent to the senses, when the decomposition of air takes place in a more rapid manner; for this purpose iron is excellently adapted, as it possesses a much stronger affinity for the base of respirable air than mercury. The following elegant experiment of Dr. Ingenhousz, upon the combustion of iron, is well known. Take a piece of fine iron wire, twisted into a spiral; fix one of its extremities into a cork, adapted to the neck of a bottle, and fix to the other extremity of the wire a small morsel of tinder. Matters being thus prepared, fill the bottle with air deprived of its mephitic part, then light the tinder, and introduce it quickly with the wire upon which it is fixed into the bottle, which you stop up with the cork. The instant the lighted tinder comes into contact with the vital air, it begins to burn with great intensity; and, communicating the inflammation to the iron wire, it too takes fire, and burns rapidly, throwing out brilliant sparks: these fall to the bottom of the vessel in rounded globules, which become black in cooling, but retain a degree of metallic splendour. The iron thus burnt is more brittle even than glass, is easily  
reduced



reduced into powder, and is still attractible by the magnet, though not so powerfully as it was before combustion.

Lavoisier repeated this experiment with a view to ascertain the products. Having filled a bell-glass of about six pints measure, with pure air, or the highly respirable part of air, he transported this jar by means of a very flat vessel into a quicksilver bath, taking care to render the surface of the mercury perfectly dry, both within and without the jar, with blotting paper. He then provided a small cup of china-ware, very flat and open, in which he placed some small pieces of iron, turned spirally, and arranged in such a way as seemed most favourable for the combustion being communicated to every part. To the end of one of these pieces of iron was fixed a small piece of tinder, to which was added about the sixteenth part of a grain of phosphorus; and, by raising the bell-glass a little, the china-cup with its contents was introduced into the pure air. It is true that by this means some common air must mix with the pure air in the glass; but this, when it is done dextrously, says Mr. Lavoisier, is so very trifling, as not to injure the success of the experiment. This being done, a part of the air was sucked out from the bell-glass, by means of a syphon, so as to raise the mercury within the glass; and to prevent the mercury from getting into the syphon, a small piece of paper was twisted round its extremity. In sucking out the air, if the motion of the lungs only be used, we cannot make the mercury rise above an inch or an inch and a half: but, by properly using the muscles of the mouth, we can, without difficulty, cause it to rise six or seven inches.

He then took an iron wire, properly bent for the purpose, and making it red-hot in the fire, pressed it through the mercury into the receiver, and brought it in contact with the small piece of phosphorus attached to the tinder. The phosphorus instantly took fire, which communicated to the tinder, and from that to the iron. When the pieces have been properly arranged; the whole iron burns, even to the last particle, throwing out a white brilliant light, similar to that of Chinese fire-works. The great heat produced by this combustion melts the iron into round globules of different sizes, most of which fall into the china-cup; but some are thrown out of it, and swim on the surface of the mercury. At the beginning of the combustion, there is a slight augmentation in the volume of the air in the bell-glass, from the dilatation caused by the heat; but presently afterwards a rapid diminution of the air takes place, and the mercury rises in the glass, insomuch that when the quantity of iron is sufficient, and the air operated upon is very pure, almost the whole air employed is absorbed.

It is proper to remark in this place, that, unless in making experiments for the purpose of discovery, it is better to be contented with burning a moderate quantity of iron; for when this experiment is pushed too far, so as to absorb much of the air, the cup which floats upon the quicksilver approaches too near the upper part of the bell-glass; and the great heat produced, which is followed by a very sudden cooling, occasioned by the contact of the cold mercury, is apt to break the glass, in which case the sudden fall of the column of mercury, which happens the moment the least flaw is produced in the glass, causes such a wave, as throws a great part of the quicksilver from the basin. To avoid this inconvenience, and to insure success to the experiment, one dram and a half of iron is sufficient to burn in a bell-glass, which holds about eight pints of air. The glass ought likewise to be strong, that it may be able to bear the weight of the column of mercury which it has to support.

By this experiment it is not possible to determine at one time, both the additional

additional weight acquired by the iron and the changes which have taken place in the air. If it is wished to ascertain what additional weight has been gained by the iron, and the proportion between that and the air absorbed, we must carefully mark upon the bell-glass, with a diamond, the height of the mercury, both before and after the experiment. After this, the syphon, guarded as before with a bit of paper to prevent its filling with mercury, is to be introduced under the bell-glass, having the thumb placed upon the extremity of the syphon, to regulate the passage of the air, and by this means the air is gradually admitted, so as to let the mercury fall to its level. This being done, the bell-glass is to be carefully removed, the globules of melted iron contained in the cup, and those which have been scattered about, and swim upon the mercury, are to be accurately collected, and the whole is to be weighed. The iron will be found in that state called martial ethiops by the old chemists, possessing a degree of metallic brilliancy, very friable, and readily reducible into powder, under the hammer, or with a pestle and mortar. If the experiment has succeeded well, from 100 grains of iron will be obtained 135 or 136 grains of ethiops, which is an augmentation of 35 per cent.

If all the attention has been paid to this experiment which it deserves, the air will be found diminished in weight exactly equal to what the iron has gained. Having therefore burnt one hundred grains of iron, which has acquired an additional weight of thirty-five grains, the diminution of air will be found exactly seventy cubical inches; and as it is known that the weight of vital air is very near half a grain for each cubical inch, the augmentation of weight in the one exactly coincides with the loss of it in the other.

If it be required to examine the nature of the air, which remains after this experiment, we must operate in a somewhat different manner. After the combustion is finished, and the vessels have cooled, we first take out the cup, and the burnt iron, by introducing the hand through the quicksilver, under the bell-glass; we next introduce some solution of potash, or caustic alkali, or of the liver of sulphur, or such other substances as are judged proper for examining their action upon the residuum of air. After this examination, so much water must be let into the glass as will displace the quicksilver; and then, by means of a shallow dish placed below the bell-glass, it is to be removed into the common water pneumatico-chemical apparatus, where the air remaining may be examined at large, and with great facility.

When very soft and very pure iron has been employed in this experiment, and when the combustion has been performed in the purest respirable or vital air, free from admixture of the noxious or mephitic part, the air which remains after the combustion will be found as pure as it was before; but it is difficult to find iron entirely free from a small portion of charry matter, which is chiefly abundant in steel; and it is likewise exceedingly difficult to procure pure air perfectly free from some admixture of mephitics, with which it is almost always contaminated: that species of noxious air does not, as Mr. Lavoisier affirms, in the smallest degree disturb the result of the experiment, as it is always found at the end exactly in the same quantity as at the beginning.

The calcination of metallic substances by the action of acids, is evidently an operation of the same nature as that which is effected by heat and vital air. Numberless experiments have shewn that vital air is a component part of acids. But this being a modern discovery, the theory of phlogiston was applied to the acids which were supposed to be capable of attracting or expelling that principle from  
metallic



metallic bodies as well as other substances. On this head the several articles relating to the acids and metals may be consulted. It must nevertheless be admitted, that as the vital air is known to be a component part of acids, as they lose a portion of it whenever they are employed to calcine any metal, as the calx is found to have gained this very principle, it appears unnecessary or redundant to admit the phlogiston in explaining these effects. The general facts of metallic solution are \*,

1. The metals cannot unite with acids unless previously calcined, or united with the base of vital air. This therefore appears to be the medium of the union.

2. The degree of calcination for this purpose is definite. If too near the metallic state, they are difficultly taken up, and if too much calcined they cease to be suspended.

3. This degree differs in the several metals.

4. In every metallic solution by an acid, the metal attracts and combines with vital air, either from the acid which is decomposed, or from the atmosphere which is rendered less salubrious, or else from the water which is decomposed. See WATER. In the first case, one of the principles of the acid, or its base, is set at liberty, and usually flies off, as sulphur in the decomposition of vitriolic acid, in the composition of vitriolic air, or either nitrous or azotic air when nitrous solutions are made. See ACID VITRIOLIC, ACID NITROUS. In the second case, as in the acetous solution of copper, which only takes place when atmospheric or vital air is present, this last fluid is absorbed. And in the third there is a disengagement of inflammable air. It is deduced that the inflammable air is afforded by the decomposition of the water, because the acid is found, when disengaged from the metal †, to be capable of forming as much neutral salt with an alkali as a like quantity of the same acid would do.

5. The marine acid, and such vegetable acids as are composed of bases which have a stronger attraction for vital air than the metals have, are not decomposed by the metals, and accordingly they are not dissolved unless water or vital air be present in sufficient abundance. And these solutions either emit inflammable air, or do not effervesce at all.

6. The disposition of these acids to unite with the calx or combination of metal and vital air greatly favours the attraction of that fluid. So that metals which would long remain exposed to the air without calcination will attract vital air when in contact with an acid: and other metals, copper for instance, which is not capable of decomposing water alone at any obtainable temperature, will effect it by the help of an acid.

There are some cases in which the water and the acid are at the same time decomposed by the metal, as in the solution of tin by the nitrous acid. Tin is so strongly attractive of vital air, and requires so large a quantity for its saturation, that after having absorbed that of the nitrous acid, and reduced it to the state of azotic or phlogisticated air, it decomposes the water and disengages inflammable air. These two principles being thus separated from their first compounds unite together, and form volatile alkali. See VOLATILE ALKALI. Hence there is no perceptible disengagement of elastic fluid. In this case it appears, that the formation of volatile alkali, in the solution of tin by the nitrous acid, always takes place;

\* Fourcroy on Kirwan.

† This experiment was well performed by Dr. G. Fordyce with zinc and vitriolic acid. See Phil. Transf. or the article ZINC.

for by throwing quicklime or caustic fixed alkali into this solution, there is always a disengagement of ammoniac.

7. It follows from all that has hitherto been said, that in every metallic solution in which the acid is decomposed, two doses of this salt are required, of which the mind conceives the necessity. 1. That whose decomposition supplies the metal with vital air. 2. That which dissolves the calcined metal.

8. Hence, if no greater quantity of acid be added to a metal than is necessary for its calcination, it will be calcined and not dissolved. Thus it is that a few drops of concentrated nitrous acid being thrown upon tin, antimony, bismuth, and even zinc, quickly reduce the metals into white, dry, and pulverulent calces.

9. From this accurate distinction of the two doses of acid, we see why a metal, though very greedy of vital air, does not decompose this acid sufficiently, nor deprive it of enough of vital air to saturate itself; for if too highly charged with this principle, it would not unite to the undecomposed portion of the acid, and there would be no solution; but instead of saturating itself in this manner, in proportion as the metal arrives at the determinate point of calcination, the acid dissolves it, and the metal does not decompose it beyond that point, because its affinity with the acid is then stronger than with a greater dose of vital air.

10. Various circumstances, and especially an elevated temperature, change these attractions; they increase that of the metal for vital air; and by favouring its saturation with that principle, they either prevent its uniting with the acid, or effect its separation: the former event takes place in the mixtures of acids and metals, whose mutual action is increased by a strong temperature, and the latter takes place in most metallic solutions, when they are too strongly heated.

11. Most metallic solutions, which are left exposed to the air, absorb vital air with more or less facility; and the metals which they contain, becoming more calcined than before, separate and fall down; so that there is not one of these solutions which remains in the same state if exposed to air, or which can be considered as absolutely permanent.

12. Since the metals cannot remain united to the acids, but in the state of calces of a determinate degree, it is easily conceived, that by plunging into a metallic solution a metal which has a stronger affinity with vital air than that which is dissolved, the former must deprive the latter of its vital air, take its place in the acid, and cause the second to subside in a form more or less metallic, accordingly as it has deprived it of more or less vital air. This is the reason of the precipitation of silver by copper, copper by iron, &c.

It may easily be perceived that the great questions relating to phlogiston in the calcination, solution, and precipitation of metallic substances are intimately connected with the composition and decomposition of water. On these subjects see WATER, PRECIPITATES, VEGETABLES.

**PHOSPHORUS (ENGLISH), OR KUNCKEL'S PHOSPHORUS.** The name phosphorus is applied to all substances capable of giving light in the dark; such as glow-worms, rotten-wood, diamonds after having been exposed to the sun or light; the Bolognian stone, and certain spars after calcination. The effects of these phosphoric matters may proceed from electricity, or some property of light. We shall mention these in the following article. The phosphorus we now treat of is of a very different nature. It is a substance not only luminous in the dark, but also inflammable and burning. It is the basis of a peculiar acid, and is consequently a species of sulphur.

The discovery of this phosphorus is not very ancient: it was discovered by a citizen



citizen of Hamburg, called Brandt, in his researches for the philosopher's stone. Kunckel was desirous to acquire this secret, and for this purpose associated himself with one of his friends, called Kraaft, who thinking by means of it to make a fortune, resolved, after having procured it, not to reveal it, and even obtained a promise from the inventor not to communicate it to Kunckel. Kunckel, vexed by this treachery, resolved to search for the phosphorus: and although he knew no more of the process than that urine was the substance employed, he prosecuted this inquiry with such zeal, that at length he made phosphorus. This chemist took to himself very justly the honour of having discovered it, and was accordingly considered as one of the discoverers of it, with so much more reason, as he did not find it by chance, and without searching for it, as Brandt had done, but after a rational inquiry undertaken for this purpose. Accordingly Kunckel's name is affixed to this phosphorus, which is commonly called the phosphorus of Kunckel.

The celebrated Mr. Boyle has also had the reputation of having made this discovery. Those who give him the credit of this say, that Boyle having seen a piece of phosphorus in England in 1679, which Kraaft had brought thither to shew to the King and Queen of England, and having been informed only that this phosphorus was produced from some matter belonging to the human body, attempted, like Kunckel, to discover the method of preparing it, and in the following year actually made a small quantity, which he lodged with the Secretary of the Royal Society, who gave him a receipt for it. But Stahl, in a small work called the Three Hundred Experiments, says, that Kraaft told him that he communicated the process to Mr. Boyle. If this be true, Boyle has claimed the honour of a discovery to which he had no right; an imputation injurious to the reputation of a man so justly famous. But it must be acknowledged, that the truth of this imputation is very questionable. For Kraaft, who, as Stahl relates, was ignorant of chemistry, and who had been treacherous to Kunckel, was nothing in all this affair of phosphorus, but a trader in secrets. For having purchased the secret of preparing phosphorus, he sold it again every where; and therefore no credit is to be given to the testimony of such a man.

It is not indeed probable, that a man of such undoubted integrity as Boyle would have communicated the process to the Royal Society as his own, if this had been the case. Neither does the invention appear to be of that magnitude, as not to be easily hit upon by those who were determined to spare no pains nor attention in the pursuit of discovery, as was the case with the chemists of that day, most of whom indulged extravagant hopes. The process of Boyle consisted in nothing more than distilling urine, till the last volatile product came over, which is the phosphorus; and he used no other artifice to facilitate the operation, than that of first evaporating the fluid part of the urine until it became of the consistence of syrup. He then mixed this liquid with thrice its weight of fine sand, and exposed the whole to distillation for twelve hours, the fire being made as intense as possible for the last six hours.

Boyle communicated the process for making phosphorus to a German chemist called Godfreid Hantkwitz, who accordingly prepared it in London. Kunckel and he were then the only persons who made any considerable quantity of it, and the latter made a lucrative trade of it. Stahl says, that he knew also this Mr. Hantkwitz, and considered him as a good practical chemist, and that he had an excellent laboratory in London. His descendant still keeps a respectable chemist's shop in Southampton-street, Covent Garden, which has always been famous for the extreme purity of the articles sold. The date 1680 is over the door.

Processes

Processes for making phosphorus were frequently published about that time. Mr. Hellot, in his Memoir on this subject, enumerates all that were then known, namely, the process published by Boyle in 1680, in the Philosophical Transactions, No. 196; that of Kraaft; for, after selling the secret to many persons, he afterwards published it in a treatise concerning phosphorus, written by the Abbé de Commieres, published in the *Mercure Galant*, for June 1683; that of Brandt, in a collection of Experiments and Observations of Dr. Hook, published by Mr. Derham in 1726; that of Mr. Homberg, in the *Ancient Memoirs of the Academy* in 1692, who says, that he had seen Kunckel make phosphorus; and lastly, the processes found in the works of several chemists, particularly of Theikmeyer, Hoffman, and Neeventuit.

But notwithstanding all these processes, whether they were not sufficiently complete, or too laborious and expensive, no chemist, excepting Hantkowitz, made phosphorus, and the operation still continued a secret till the year 1737, when a stranger came into France, who offered to make phosphorus. The ministry granted him a reward for his process, which he accordingly communicated. Messrs. Hellot, Dufoy, Geoffroy, and Duhamel, all experimental philosophers and chemists of the Academy of Sciences, executed this process successfully. Mr. Hellot wrote a distinct account of it, and published it amongst the *Memoirs of the Academy of Sciences* for the year 1737; a large extract of which may be found in the *Elements of Practical Chemistry*.

Since the publication of the Memoir of Mr. Hellot, the process of phosphorus was no longer a secret. But as this operation has hitherto been rather curious than useful, and is also expensive and troublesome, Macquer says, he does not know that any French chemist repeated it at that time, excepting Mr. Rouelle, who soon afterwards began a course of chemistry, in which he undertook to make phosphorus in the presence of his pupils. Macquer was then present as one of these, and Hellot attended during the whole operation. The pupils continued there the whole night: but from a fault in the retort this first operation failed. However, in the year following Mr. Rouelle succeeded many times.

To make phosphorus by Mr. Margraaf's process, a kind of *plumbum corneum* is previously prepared, by distilling a mixture of four pounds of minium with two pounds of powdered sal ammoniac, from which all the volatile alkali, which is very penetrating, is by this operation obtained. The residuum after the distillation, that is, the *plumbum corneum*, is to be mixed with nine or ten pounds of extract of urine boiled to the consistence of honey. Margraaf requires that this urine should be putrefied, which is unnecessary according to Baumé's observation\*. This mixture is to be made slowly in an iron caldron set upon the fire, and by frequently stirring the matters. Half a pound of powdered charcoal is then to be added, and evaporation is to be continued till the whole is reduced into a black powder. This powder is to be put into a retort, to extract from it, by a moderate and graduated heat, all the volatile products of urine; that is, volatile alkali, fetid oil, and an ammoniacal matter which adheres to the neck of the retort. In this distillation the heat is to be only raised so as to make the matter red hot. After the distillation, a black and friable residuum

\* Schlosser (*de sale urinæ nativo*) says, that a greater quantity of phosphorus may be procured from fresh than from putrid urine. But Venel (*Encyclop. tom. xiv. p. 923.*) thinks it may be more easily obtained from putrefied urine; and Pott says, that urine when putrefied yields a larger quantity than when fresh.



remains, from which the phosphorus is to be extracted by a second distillation, and a stronger heat. Before it is exposed to another distillation, it may be tried, by throwing some of it upon hot coals. If the matter has been well prepared, a smell of garlic exhales from it, and a blue phosphorical flame is seen, undulating along the surface of the hot coals.

This matter is to be put into a good earthen retort capable of sustaining a violent fire. Margraaf recommends retorts of Waldenburgh, or those which are made near Kirchan in Saxony; but in France, they use Hessian retorts, although they have the inconvenience of allowing a large quantity of phosphorus to transpire during the operation. Baumé secures his retorts with a covering of clay and hair. Our Staffordshire potters make good earthen retorts for this purpose. See COATING.

Three quarters of the retort are to be filled with the matter which is to yield the phosphorus. It is to be placed in the common furnace for distillation with a retort; excepting that, instead of being terminated by an ordinary reverberatory or dome, this ought to be terminated by the upper piece of an air-furnace, to which a tube is to be applied, the diameter of which ought to be from four to six inches, according to the size of the furnace, and the height from eight to nine feet. This apparatus, which Baumé uses, is necessary for raising a sufficient heat, and for the convenience of throwing in a sufficient quantity of fuel through the door of the upper piece of the furnace. The retort ought to be well luted to a receiver of moderate size, pierced with a small hole, and half full of water. For this purpose ordinary fat lute may be bound on with strips of linen, dipped in a lute prepared with lime and whites of eggs. The hole in the furnace through which the neck of the retort passes ought to be well stopped with furnace earth. Lastly, a small wall of bricks is raised betwixt the furnace and receiver, to guard this vessel against heat as much as is possible.

All these preparations being made the evening before the distillation is to be performed, we are then capable of proceeding to this operation, which is very easy. The retort is to be heated by slow degrees during an hour and a half; and then the heat is to be increased till the retort be red hot, and the phosphorus begins to pass in luminous vapours: when the retort is almost of a white-red heat, the phosphorus passes in drops, which fall and congeal in the water at the bottom of the receiver. This degree of heat is continued till no more passes into the receiver. When a retort contains eight pints or more, this operation continues about five hours.

Margraaf's apparatus is somewhat different from that above described. He divides the whole quantity of matter from which the phosphorus is to be obtained into six small retorts, which he places in a furnace that he describes. The advantage of this division is, that if any accident happens to one retort, the whole matter is not lost; and as the retorts are smaller, a less heat is required. If indeed much phosphorus was to be made, this practice would be safe and excellent; but Macquer affirms, that the method above described of Baumé is very convenient when a large quantity of phosphorus is not wanted, and that he has never seen it fail.

Phosphorus does not pass pure in this distillation, but is blackened by soot or coal, which it carries along with it: it may easily be purified and rendered white and fine by a second distillation or rectification. This rectification is made in a small glass retort, to which is adjusted a small receiver half full of water. A very gentle heat is sufficient, because phosphorus once formed is very volatile: and

and as the fuliginous matter with which it is soiled was raised merely by the violence of the heat, it remains at the bottom of the retort in this distillation, and the phosphorus passes very pure.

The phosphorus is then usually divided into small cylindrical rolls, for the convenience of using it. This is done by putting it in glass tubes immersed in warm water. This very gentle heat is sufficient to liquefy the phosphorus, which is almost as fusible as suet. It takes the form of the glass tubes, from which it may be taken out when it is cold and hardened. That it may be more easily taken out of the tubes, these must be somewhat of the form of frustums of cones. All these operations ought to be made under water, to prevent the inflammation of the phosphorus.

The process published by Hellot for the preparation of phosphorus is only different from this in two respects; first, that his is only one operation, and not divided into two, as Margraaf's is; and, secondly, that he does not use *plumbum corneum*. The operation is certainly much facilitated by Margraaf's method of separating the volatile matters of the urine by a previous distillation; because after that, nothing more is requisite but to apply heat sufficient to raise the phosphorus; which may be done in four or five hours, whereas without this previous operation the distillation lasts 24 hours. The advantage of the *plumbum corneum* was long a matter of doubt; but since it has been ascertained, that the acid of phosphorus exists in urine in two combinations, the explanation has become easy. This acid is combined with volatile alkali and with mineral alkali. The former salt is decomposed by charcoal, and gives over phosphorus with heat, which the latter does not. But when *plumbum corneum*, or the combination of marine acid with the calx of lead, is added, the marine acid seizes the mineral alkali, and forms common salt; part of the coal is employed in reducing the lead, and another part in reducing the disengaged phosphoric acid, which then comes over in the form of phosphorus.

The process for disengaging phosphorus from bones has already been described under the article phosphoric acid, which see. The phosphoric glass obtained in the first instance from bones, is not sufficiently deprived of calcareous earth to be used in any other process than that of making phosphorus. For this purpose however it is not necessary to bring it to the consistence of glass. The evaporation may be conveniently performed in a copper vessel; and when the fluid has acquired the consistence of syrup, it may be mixed with its own weight of charcoal in powder, and submitted to distillation in a good earthen retort. Instead of applying a receiver, the neck of the retort may be immersed in a basin of water to a small depth; and the phosphorus, as it comes over, will fall in drops to the bottom. It is true that in the process thus managed there will be apparently much phosphorus burned by the admission of the common air, which now and then passes into the neck of the retort, whenever the absorption of the water causes its surface to fall below the aperture; but this quantity is really inconsiderable, and is compensated by the simplicity and facility of the process. The operator must be careful that the neck of the retort be not plunged to too great a depth; because in this case the water would pass into the body of the retort at the time of absorption, before the surface of the water in the basin had fallen sufficiently to admit the air. The phosphorus comes over as soon as the retort is red hot; and when the drops cease, the whole apparatus must be suffered to cool. It has the form of reddish wax or tallow; and may be pressed together under the water while it is yet warm. If this be done with the naked hand, great care must be



be taken, that no particle shall remain sticking to the hands, or under the nails; as such a particle, by taking fire when brought into the air, might produce very painful and disagreeable consequences. It may be moulded into sticks, by putting the pieces into small conical tubes of glass, closed at one end, and fixed upright in a piece of wood, the whole being immersed under water: on heating the water, the phosphorus will melt, and take the desired form. The impurities that rise to the upper ends of the tubes may be cut off when taken out, which must not be done till all is cool.

Phosphorus may be had exceedingly pure by straining it through a leather bag immersed in hot water; or, which is still better, by distilling it a second time with a very gentle heat, as already mentioned. The blackish colour of phosphorus is ascribed to a portion of phosphoric acid which is mixed with it. This disappears almost entirely by boiling with a small quantity of volatile alkali; and if the phosphorus be boiled two or three successive times in ardent spirit, it becomes perfectly transparent, and of a beautiful opal colour, with very little loss of weight.

Phosphorus must be kept in a bottle of water, to prevent its gradual combustion.

The method of procuring phosphorus by distillation from urine was superseded by the easier method of Scheele, by which it is obtained from bones. This method is accordingly used by most chemists; but M. Giobert of Turin has since improved the process with urine so much as to exceed in simplicity and cheapness that of Scheele; inasmuch that the phosphorus may, without any offensive operation, be procured with convenience and certainty in the course of a day, or even a few hours, if the quantity be small. From the consideration of what happens by the addition of plumbum corneum in the distillation of phosphorus, this chemist inferred that the marine acid seized the volatile and mineral alkalis of the urine, while the disengaged phosphoric acid combined with the lead, and formed a compound consisting of two parts, both reducible by charcoal, but not both volatile and therefore separable by heat. It might however be questioned, as far as could be deduced from experiment in the dry way, whether the charcoal were not originally concerned in the decomposition, and whether the affinities were not different in a lower temperature, as is seen in other chemical facts. Hence it remained to be tried, whether the combination would equally take place in the humid way, or with pure urine, without any previous concentration by the disgusting process of evaporation. For if the decomposition of the phosphoric salts could be had by the intermedium of the marine salt of lead, or any other metallic salt, and the metal were to fall down in the form of an insoluble compound with the phosphoric acid; this compound might beedulcorated and exposed to distillation with charcoal. M. Giobert had observed that the phosphoric acid, by simple elective attraction, is capable of decomposing the acetous and even the nitrous salts of lead. He had, therefore, every reason to expect success by double affinity with urine. The success was equal to his expectation. Sugar of lead, or the combination of lead with vinegar, was added to urine. A precipitate fell down, on which he poured vitriolic acid. The supernatant liquor being decanted, and saturated with volatile alkali, proved to be a phosphoric salt, and the nearly insoluble residue was vitriolated lead. From these facts it was clear, that the first precipitate was phosphorated lead, that the vitriolic acid seized the lead, and disengaged the phosphoric, and that this last formed a neutral salt by the addition of volatile alkali.

This is a ready method of procuring phosphorated volatile alkali for essays by the

the blow-pipe, and may be more cheaply performed by the addition of vitriolic ammoniac, which is the product of various operations, less expensive than those by which the acid and alkali are obtained separate. Mild volatile alkali will also decompose the phosphorated lead; but in this case a triple compound of phosphoric acid, volatile alkali, and calx of lead is obtained. No such effect happens with the vitriolic ammoniac.

As the phosphorated lead affords phosphorus by distillation with charcoal, so may the experiment be performed with advantage with other metallic salts. M. Giobert, however, found lead the best. The vitriol of zinc decomposes the resinous salts very well, but the volatility of this metal greatly embarrasses the subsequent operation. For though the phosphorus appears to rise with rather more facility than the zinc, yet the greater part of the product is phosphorated zinc, which sublimes in the retort. Mercury is subject to an objection of a similar kind.

The quantity of urine for making phosphorus may be procured at the hospitals, or, if more convenient, at the stables; for M. Giobert did not find any difference of importance in the urine of men or horses, or whether in health or sick. He thinks fresh urine preferable to that which has putrefied, or at least not inferior to it. A solution of lead is then to be made in the nitrous acid, and poured by a little at a time into the urine, until no more precipitate is afforded, as may be ascertained in the usual way by trial with smaller portions taken out. The whole mixture must then be diluted with much water to rarefy the extractive matter. By straining through a cloth, the watery liquid is separated from the precipitate. M. Giobert does not say whether it would be any object of profit to recover the nitrous salts from the solution. The precipitate is to be made into a paste with charcoal, and well dried in an iron or rather a copper pot. It is then fit for distillation. An oily alkaline fluid first comes over, then a small portion of empyreumatic oil, both which arise from the urine left in the interstices of the precipitate. As soon as the oil has ceased to come over, the receiver must be changed, the fire raised, and a receiver with water (see APPARATUS) substituted, as in the ordinary method. The phosphorus sometimes begins to appear in about half an hour, and the accomplishment of an operation, which affords 12 or 14 ounces of phosphorus, is easily effected in eight hours. The author thinks that a less degree of heat is requisite than in the process with bones.

Sugar of lead may be used instead of the nitrous solution, in all places where its cheapness as an article of commerce may render it preferable. But in this case, much of the lead falls down in the form of calx, and it is also necessary to keep the urine for some hours in digestion (I suppose with heat) after the sugar of lead is added. The precipitation of more calx may be in some measure remedied by the previous addition of vinegar.

M. Giobert remarks, that it is not easy to determine with exactness the quantity of phosphorus obtained from a given quantity of the precipitate, as it seems in some measure to depend on the nature of the urine, and certainly upon the care used in the edulcoration. When the precipitate of lead is well washed and saturated completely with phosphoric acid, he thinks his experiments indicate that 100 parts of the phosphorated lead afford 14 or 18 parts of phosphorus. The lead is found reduced in the retort, and in part repays the charges. The phosphorus is soiled by the oily matter it dissolves in passing through the neck of the retort, but it may be easily purified by the well known processes.

The



The acidification of phosphorus is treated of under the article **ACID PHOSPHORIC**, which see.

Phosphorus combines with the caustic fixed alkalis in a boiling heat, and forms an *hepar*; during which a peculiar elastic fluid is given out, which possesses the remarkable property of taking fire as soon as it communicates with the air of the atmosphere. This air has evidently the same relation to phosphorus as the common hepatic has to sulphur; and, like that, it probably consists of a solution of the phosphorus in inflammable air. See **AIR PHOSPHORIC**.

Sulphur and phosphorus unite by fusion, and form a solid compound of a fetid smell, which burns with a yellow flame, and swells in water; at the same time communicating acidity to that fluid, and emitting a smell of hepatic air. All kinds of oils dissolve phosphorus, and are rendered luminous by it; several essential oils form a solution which takes fire by exposure to the air, probably in consequence of the emission of phosphoric air. The butter of wax, which consists of wax deprived of part of its acid by distillation, is said to be the properest material for producing this effect.

The combustible property of phosphorus has been lately applied in various ways to procure fire; but the danger of spontaneous accension in improper situations, and the expence, have prevented its coming at all in competition with the ordinary method of flint and steel. The phosphoric contrivances are a phosphoric taper or match, and a bottle, the method of making which is as follows:

1. The most simple process for making the phosphoric matches consists, in taking a glass tube, four inches long, and one line in diameter, closed at one end. A small quantity of phosphorus is introduced into the tube, and pushed to its further end; after which a taper covered with a small quantity of wax is introduced into the same tube. The open end is then hermetically sealed, and the other end is plunged into boiling water. The phosphorus melts, and fixes itself upon the match.

A line is drawn at one-third of the length of the tube, with a flint, that it may be broken as occasion may require.

The match is to be drawn out quickly, to inflame the phosphorus.

The process of Mr. Lewis Peyla, to make the inflammable bougies, consists in taking a glass tube, five inches long and two lines wide, one end of which is sealed with the blow-pipe. Small tapers of wax are prepared with three double threads of cotton twisted together. The extremity of the match or taper is half an inch long, and must not be covered with wax.

A piece of lead is laid in a saucer filled with water; and upon this the phosphorus is cut, beneath the water, into fragments of the size of a grain of millet. One of these grains is to be dried and introduced into the tube of glass; after which the fortieth part of a grain of very dry sulphur is to be added, that is to say, half the weight of the phosphorus. One of the bougies is then taken, and its extremity dipped in very clear oil of wax. If too large a quantity rises, it must be dried with a cloth.

The match is introduced into the tube, with a turning or twisting motion between the fingers.

The bottom of the tube must then be plunged into boiling water to soften the phosphorus; observing to keep it no longer than three or four seconds in the water.

The other extremity of the tube is afterwards sealed.

These

These bougies must be kept in a tin tube, to avoid the danger of inflammation.

2. To form the phosphoric bottles, a glass bottle is heated by fixing it in a ladle full of sand, and two or three small pieces of phosphorus are then introduced into it. A small red-hot iron wire is used to stir the phosphorus about, and cause it to adhere to the internal surface of the bottle, where it forms a reddish coating. The heated wire is introduced repeatedly; and when all the phosphorus is thus distributed within the bottle, it is left open for a quarter of an hour, and afterwards corked. When this is used, a common match tipped with sulphur is introduced into the bottle, turned round, and quickly drawn out. The phosphorus which sticks to the sulphur takes fire, and lights the match.

The theory of this phenomenon depends on the circumstance that the phosphorus is strongly dried or half calcined, and needs only the contact of air to set it on fire.

Very strong ardent spirit dissolves a portion of phosphorus when cold, and more when heated, which is again separated by cooling. Metals do not readily combine with this substance when simply heated with it; but when the phosphoric acid, together with charcoal, is exposed to a strong heat, a considerable number of the metals may be made to unite with it, probably in consequence of their being previously calcined by the acid. See the several metals.

Chaptal conjectures that the luminous matter of the glow-worm, *lampyris splendidula* Linnæi, and other lucid animals, is a combination of phosphorus and oil. Forster of Gottingen observes, that the shining matter of the glow-worm is liquid. If the glow-worm be crushed between the fingers, the phosphorescence remains on the finger. Henckel reports, in the eighth dissertation of his *Pyritologia*, that one of his friends, of a sanguine temperament, after having danced much, perspired to such a degree that he thought his life in danger. While he undressed, traces of phosphoric flame were seen on his shirt, which left yellow-red spots behind them, resembling the residue of burnt phosphorus: this light was long visible.

**PHOSPHORIC STONES, OR EARTHY PHOSPHORI.** These stones when properly calcined have the property of shining in the dark. The most celebrated and most anciently known phosphorus of this kind is that called the Bolognian stone, from Bologna, a city of Italy, near which this stone is found. See **BOLOGNIAN STONE.** It is the ponderous spar.

The marine salt of lime is easily fused, and, being poured into a clean iron mortar, appears when cold of a yellowish white colour, and semi-transparent like horn. It is luminous when struck in the dark, and thence was called a phosphorus by Homberg. The experiment does not always succeed, probably for want of combustible matter, which is usually present when this compound is obtained from the residue of impure sal ammoniac distilled from lime. Solution of chalk in the nitrous acid forms on evaporation a tenacious mass like turpentine, which, dried and calcined a little, proves luminous in the dark. This phosphorus is usually distinguished by the name of its first discoverer, Baldwin: it is called also phosphorus hermeticus, from its being kept in hermetically sealed glasses to secure it from the air. It differs from some other natural phosphori, in appearing in some degree luminous after exposure to the light of a taper, as well as of the sun.

The effect of the earthy phosphori seems to depend on a degree of slow combustion, not yet well explained. These substances seem to resume vital air and moisture from the atmosphere, and emit light either on the principle of common



combustion, or from previous absorption. According to this last opinion, the shining of phosphori, after exposure to light, is not a mere combustion produced by the action of the luminous body, but an absorption and emission of the matter of light.

The late Mr. Canton gave a receipt for making an artificial phosphorus, greatly superior to any single natural substance, with the additional advantage of being very easily and cheaply prepared. His receipt is as follows: Calcine some common oyster shells, by keeping them in a good coal fire for half an hour, and let the purest part of the calx be pulverized and sifted. Mix with three parts of this powder, one part of the flowers of sulphur; let this mixture be rammed into a crucible of about an inch and a half in depth till it be almost full, and let it be placed in the middle of the fire, where it must be kept red-hot for one hour at least, and then set by to cool. When it is cold, turn it out of the crucible, and, cutting or breaking it to pieces, scrape off, upon trial, the brightest parts; which, if good phosphorus, will be a white powder, and may be preserved by keeping it in a dry phial with a ground stopple.

The quantity of light which a little of this phosphorus gives, when first brought into a dark room, after it has been exposed for a few seconds on the outside of a window, to the common light of the day, is sufficient to discover the time by a watch, if the eyes have been shut, or in the dark, for two or three minutes before.

By this phosphorus celestial objects may be very well represented, as Saturn and his ring, the phases of the moon, &c. if the figures of them made of wood, be wetted with the white of an egg, and then covered with the phosphorus. And these figures appear to be as strongly illuminated in the night, by the flash from a near discharge of an electrified bottle, as by the light of the day.

John Baptist Beccaria discovered that the sulphureo-calcareous phosphorus imbibed the peculiar coloured rays to which it had been exposed. Thus having exposed different phosphoric pieces to rays of the sun, transmitted through green, yellow, and red crystals, he observed that each of them, when afterwards viewed in the dark, exhibited that colour to which it had been exposed.

**PIMENTO.** See **PEPPER (JAMAICA).**

**PIPE-CLAY.** The difference between the porcelain clay and those of more moderate purity, called pipe-clays, of which we have plenty in Devonshire, is commonly, that the former remains white when burned in an open fire; but the latter, containing a portion of mineral oil, becomes of a blueish-gray in a moderate heat, by the coal produced by this combustion. A stronger heat, however, will perfectly consume this coal, and restore the whiteness. On the whole, however, it appears rather as if this distinction between the clays used in pottery were grounded on the nature of the product they afford, than on any very evident property ascertainable before they are wrought and baked.

**PISOLITHES.** A stalactitical calcareous stone of a gray colour, arising from calx of iron.

**PITCH.** Tar boiled down to dryness is the common black pitch: this part of the process is commonly performed in a still, in order to save an essential oil which arises in the boiling, and which is called, from the name of the tree which tar is principally prepared from, *oleum pini*, and *oleum tædæ*. This oil is greatly valued by painters, varnishers, &c. on account of its drying quality: it soon thickens of itself, almost to the consistence of a balsam. Along with the oil there comes over a watery liquor, which the workmen injudiciously throw away: it is a good acid spirit, capable of being applied to sundry useful purposes. Neumann knew a person in France who saved by it several thousand dollars.

Pitch is not a pure and perfect resin : it has not only suffered a notable change from the heat employed in its preparation, but likewise participates of the other principles of the wood of a gummy and saline nature, and of a burnt earth. Hence its disposition to separate and precipitate when melted with oils, fats, and resins, into plasters and ointments ; and hence it is gradually corroded by air and moisture, when employed as a cement or defence for wood or other substances, in ships, land-carriages, cisterns, casks, shingle coverings for houses, &c. Ship-builders endeavour to improve their tar and pitch, so as to render them more durable, by various additions.

Two ounces of dry pitch treated by Neumann with rectified spirit of wine, gave but one ounce and half a scruple of resinous extract : half an ounce of empyreumatic oil separated during the digestion, and there remained undissolved half an ounce of earthy matter, from which water would extract nothing. The same quantity of the same pitch boiled at first in water, yielded two drams and half a scruple of gummy extract ; from the remainder nevertheless were obtained ten drams of spirituous extract, that is, near two drams more than when spirit was applied at first, the indissoluble part amounting as before to half an ounce. The distilled water smelled and tasted almost like red herrings : the spirit had no remarkable impregnation. Eight ounces of pitch, distilled in an open fire, yielded two ounces one dram and a half of an acid spirit, and two ounces five drams of a fetid oil, three ounces of a shining black coal remaining in the retort.

The foot which arises in the burning of pitch, is the substance commonly sold under the name of lamp black : in France, the pitch is burnt for this purpose in a kind of furnace made of tiles, so disposed as to prevent the escape of the smoke.

Lewis informs us that what is called lamp-black (originally the foot collected from lamps) is obtained, in different parts of Germany, Sweden, &c. not from pure resin or pitch, but from the dregs and pieces of bark of the tree separated in their preparation. For making common resin, the impure juice collected from incisions in pines and fir-trees, is boiled down with a little water, and strained whilst hot through a sack : on cooling, the resin congeals upon the surface of the water, and is then packed up in barrels ; it is distinguished according to its colour, into white, yellow, and brown. The dross left on straining, is burnt for lamp-black, in a low oven, from which the smoke is conveyed by a long passage into a square chamber, having an aperture in the top, upon which a large sack is fastened : the foot concretes partly in the sack, which is occasionally removed, and partly in the chamber and canal, from which it is swept out.

Lamp-black is more oily or resinous than the common wood foot : it gives out more to spirit and less to water by infusion, and yields a larger quantity of oil on distillation. Mixed with boiled oil, and a little boiled turpentine, it forms the black composition used as ink in printing. See INK, also PYROPHORUS.

PITCH-BLENDE. See PECH-BLENDE.

PITCH (JEWS). See ASPHALTUM.

PIT-COAL. See COAL.

PLANTS. See VEGETABLE KINGDOM.

PLASTER OF PARIS. See EARTH CALCAREOUS.

PLATINA is one of the metals for the discovery of which we are indebted to our contemporaries. It has yet been found only in Spanish America among



the gold mines there. We receive it in the form of small particles, from the minutest size up to that of a pea; though these last are very seldom met with. Its particles or grains are smooth, irregularly figured with round edges, and are flattened, probably by hammering in the mills in which the gold is amalgamated. These grains are of a whiter colour than iron, and are considerably malleable. In the state in which we receive them, they are often mixed with ferruginous sand, which may be separated by the magnet; and also with grains of quartz or crystal. When it is separated from heterogeneous particles, the crude platina itself is slightly magnetic, and is between sixteen and eighteen times as heavy as water. The most violent fires are insufficient to melt it, though its parts may be made to cohere together into a solid button by the strong heat of a wind furnace. Burning lenses of the most powerful kind fuse it, and convert it into a malleable metal; and small portions of crude platina may be easily melted upon charcoal, by flame urged by a stream of vital air.

Pure or refined platina is by much the heaviest body in nature. It is very malleable, though considerably harder than either gold or silver; and it hardens much under the hammer. Its colour on the touch-stone is not distinguishable from that of silver. When in the highest degree of purity, it is not magnetical; but when its specific gravity is as low as 21.36 it contains iron sufficient to render it magnetical. Pure platina requires a very strong heat to melt it; but when urged by a white heat, it is said that its parts will adhere together by hammering. This property, which in iron is distinguished by the name of welding, is peculiar only to platina and that metal, which resemble each other likewise in their infusibility.

Platina is not altered by exposure to air; neither is it acted upon by the most concentrated simple acids, even when boiling, or distilled from it. The dephlogisticated or aerated marine acid dissolves it, as does likewise aqua regia; and both are said to form the same salts with it. In this particular of solubility platina resembles gold.

The aqua regia best adapted to the solution of platina, is composed of equal parts of the nitrous and marine acids. The solution does not take place with rapidity. A small quantity of nitrous air is disengaged, the colour of the fluid becoming first yellow, and afterwards of a deep reddish brown, which, upon dilution with water, is found to be an intense yellow. This solution is very corrosive, and tinges animal matters of a blackish-brown colour: it affords crystals by evaporation. The metal is precipitable from its solution by sal ammoniac; a property by which it is distinguished from all other metals, in the same manner as the solution of gold is characterized by its precipitation upon the addition of martial vitriol. In this way, a compound solution of gold and platina may be separated by precipitating either of the two metals at pleasure. The orange-coloured precipitate of platina, obtained by means of sal ammoniac, is a saline substance, completely soluble in water; but its component parts have not been well ascertained. It is fusible without addition by a good forge furnace, and forms a brilliant, dense, and close-grained button, which is not malleable, probably on account of part of the saline substance not being dissipated.

The same precipitate exposed to the stronger heat of a blast furnace, was fused into a perfectly malleable regulus by the Count de Milly. See Magellan's Cronstedt, page 574. I have several specimens of this platina, which is in thin plates or bars; their specific gravity is above  $21\frac{1}{2}$ ; in which I do not pretend to a greater accuracy than 1-200th part of the weight, because the quantities are so small.

small. It is perfectly malleable, hard, and elastic, and obeys a strong magnet when the pieces are floated upon water: one small piece which was fused by Parker's lens is not at all magnetical, and seems to exceed 22 in specific gravity. Dr. Ingenhoufz possesses masses of platina of several ounces produced in this way and by welding. For this last purpose the mass at the white end is put into a tube of iron, and suddenly compressed together by a heavy blow. This platina is very malleable, and has been made into ornaments, fine wire, and other articles.

Alkalis, and the soluble earths, decompose the solution of platina, and precipitate the metal in the form of a calx. Mild vegetable alkali produces an orange precipitate in the solution of platina. This precipitate is not a calx of pure platina. Messrs. Macquer and Baumé have observed, that it owes its colour to its containing a certain quantity of acid. It is therefore to be considered as a mixture of calx of platina with muriated vegetable alkali, or a kind of triple salt. A proof of this opinion is, that when this precipitate is washed with hot water, the fluid acquires a colour by dissolving the salt of platina, and the residue is pure calx of platina of a gray colour. Fixed alkali, boiled on this precipitate, instantly deprives it of its colour, leaving a calx of platina, of a gray-white pearl colour, according to the experiments of M. Baumé. That chemist ascertained that the precipitate of platina is soluble in alkali; for, on pouring a solution of the metal into a hot solution of mild vegetable alkali, he found no precipitate produced: and the solution, precipitated by fixed alkali, always retains, on this account, a deep colour; and platina may be easily obtained by evaporating it to dryness. Margraaf discovered, that soda does not precipitate the solution of platina: but Bergman has observed, that on putting into it a great quantity of this alkali, there is a precipitate speedily enough produced.

Bergman informs us that an alkaline prussiate, highly saturated and very pure, does not precipitate the solution of platina; and that this metal is the only one not liable to be precipitated by this re-agent; and he therefore proposes it for separating the iron, which is always in union with platina.

Caustic volatile alkali produces an orange precipitate in the solution of platina. This precipitate is almost entirely saline; for water dissolves most part of it, taking a colour like that of the solution of gold. After the water has acted on this precipitate, there remains a blackish substance, which appears to be ferruginous. One essential difference between the precipitate of platina and that of gold by ammoniac is, that the former is not fulminating like the latter.

Infusion of the nut-gall produces, in the solution of platina, a deep green precipitate, which becomes gradually pale by rest.

All precipitates of the solution of platina obtained by alkaline matters, are unfit for vitrifying and colouring glass by furnace fires. In the attempts made by Messrs. Lewis and Baumé to accomplish this, the platina was always reduced to grains, which were arranged in ramifications, or a kind of checquer work. Platina may be obtained in a sort of button, by exposing these precipitates to heat, together with some reductive fluxes, such as borax, cream of tartar, glass, &c. Messrs. Macquer and Baumé melted in five-and-thirty minutes, at a forge fire blown by two strong bellows, a precipitate of platina mixed with these fluxes. They obtained, in a hard blackish glass like bottle-glass, a brilliant button of platina, which appeared to have been in fusion. This button was not ductile: it broke into two pieces; in consequence of which it was observed to be hollow within. It was nearly of the same hardness with forged iron, and made deep scratches in gold, in copper, and even in iron. Notwithstanding what has been



observed of precipitates of platina, as not being liable to vitrify or mix with glass, Baumé melted them into a vitriform matter by two different processes. The precipitate of platina, mixed with calcined borax and a very fusible white glass, and exposed for six-and-thirty hours to the heat of the hottest place of a furnace for pottery, afforded him a greenish glass, inclining to yellow, and containing no globules of reduced metal. This glass being treated anew with cream of tartar, gypsum, and potash, was thoroughly melted, but contained small globules of platina dispersed through it. M. Baumé separated them by washing, and found them to be ductile. He then, in conjunction with M. Macquer, exposed precipitate of platina in the focus of the same burning glass with which they had melted the metal. The precipitate emitted a very thick luminous smoke, which diffused a strong smell of aqua regia: it lost its red colour, and resumed the natural colour of platina; and it melted into a glossy sparkling button, which button consisted of an opaque vitrescent matter of an hyacinth colour on the surface, and blackish internally, and may be considered as a real glass of platina. Fourcroy, notwithstanding, very properly remarks, that the saline matters with which it was impregnated, must, without doubt, have contributed to its vitrification.

The precipitate of platina does not appear to be soluble in simple acids; but it dissolves readily in the aqua regia, to which it communicates only an orange colour; never a brown like platina in grains.

Messrs. Margraaf, Baumé, and Lewis mixed the solution of platina with solutions of the other metallic substances. From these experiments it appears, that almost all metals precipitate platina in a brick-red or a brown powder; and that, agreeably to what happens to most other metals, none of these precipitates possess the properties of a metal. In this there is an analogy between gold and platina; with tin, however, platina does not give a purple, but a brown precipitate inclining to red. Solutions of bismuth and lead by the nitrous acid, of iron and copper by any of the acids, and of gold by aqua regia, produce none of them any precipitate in the solution of platina, according to Margraaf: but again, solutions of arsenicated vegetable alkali, of nitre of zinc, and nitre of silver, are capable of precipitating the solution of platina: with the first it yields a scanty crystallized precipitate of a beautiful golden colour: with the second, an orange-red matter; and with the third, a yellow matter. These different precipitates have not been yet carefully examined, nor is it known by what decomposition they are produced.

This metal is scarcely affected in the dry way by saline substances, nor by sulphur, though it is said to be dissolved by liver of sulphur. Nitre, according to the experiments of Lewis and Macquer on the crude grains, affects platina in a peculiar manner. Calx of arsenic facilitates its fusion, and the semi-metal forms a brittle compound with the platina. Mr. Achard succeeded in making crucibles of platina, by fusing equal parts of platina, white arsenic, and vegetable alkali. This matter, when cooled, was reduced to a powder, and rammed into the mould of the vessel intended to be formed. A strong heat, quickly raised, and continued for some time, fused the mass; and, after dissipating the arsenic and the alkali, left the platina in the form desired.

No detonation takes place when a mixture of nitre and platina is cast into a crucible; but when a mixture consisting of one part of platina and two of nitre is exposed for a considerable time to an intense heat, as Lewis exposed it for three days and three nights successively, the metal takes a rusty appearance. If

this

this mixture be boiled in water, the fluid dissolves the alkali, which carries with it a brownish powder; and the platina separated by this washing is found to be one-third less than the original quantity. The brown powder may be separated from the alkali by filtration. This powder appears to be a kind of calx of platina mixed with a little calx of iron. Lewis caused it to take a whitish-gray colour, by distilling it many times successively with sal ammoniac. Margraaf repeated this valuable experiment, and has added two important facts: platina combined with alkali of nitre, and diluted in a certain quantity of water, forms a jelly: a portion of the metal, separated from this jelly by dilution in water and filtration, takes a black colour like pitch. From these circumstances it appears, that the platina suffers in this process some great alteration: and it is to be wished, as Fourcroy remarks, that these experiments were farther prosecuted in order to determine whether, by repeated calcination with nitre, this metal might be wholly reduced to a brown powder; as also to ascertain the state of the platina thus calcined.

The result of Dr. Lewis's experiments with crude platina and the metals is thus abridged by Macquer:

Equal parts of gold and platina may be melted in a violent fire, and the alloy which is formed may be easily poured into an ingot mould. It is whitish, hard, and may be broken by a violent blow. Nevertheless, when it has been well annealed, it is capable of considerable extension under the hammer. One part of platina and four parts of gold may be melted and alloyed with a much less fire than is requisite in the preceding experiment. This alloy is so ductile, that it may be extended into very thin plates without being broken, or even split at the edges. Dr. Lewis observed a remarkable circumstance concerning this alloy, namely, that the platina, which was  $\frac{1}{3}$  of the whole mass, rendered the gold no paler than guineas are, which contain only  $\frac{1}{12}$  of silver.

Silver and platina may be melted and alloyed together in equal parts with a very violent fire. The alloy which is formed is much harder and darker coloured than silver, and of a large grain, although it preserves some ductility. These qualities are less sensible when one part of platina is added to seven parts of silver: but this alloy is still coarser grained and less white than silver. This coarseness of grain shews an imperfect union; and indeed silver and platina do not seem to unite very intimately; for Dr. Lewis observes, that when the alloy of these two metals was left after fusion in the crucible, a considerable part of the platina was separated and sunk to the bottom. The platina did not appear to communicate any good quality to the silver, excepting a greater hardness.

Copper seems to be most improved by being alloyed with platina. When indeed a large proportion of platina is added to copper, as equal parts or two-thirds, the alloy is hard, brittle, and coarse: but when a less quantity of platina is added, as from  $\frac{1}{6}$  to  $\frac{1}{12}$ , or even less, a golden-coloured copper is produced, very malleable, harder, susceptible of a finer polish, smooth-grained, and much less subject to calcination and rust than pure copper.

Dr. Lewis was not able to fuse forged iron with platina, which is not surprising, when we consider the refractory qualities of these two metals: but he alloyed platina with cast-iron by adding one part of platina to four parts or more of the iron when it was just beginning to flow. This alloy was much harder, and much less subject to rust, than pure iron. It was susceptible of a very fine polish.

Platina may be melted with tin in all proportions from equal parts of the two metals to twenty-four parts of tin. This alloy was observed to be much harder,  
more



more brittle, more dark-coloured, and coarser, as the proportion of the platina was larger. No advantage seemed to be attainable by this allay. Lead also may be allayed in different proportions with platina, nearly as tin may, with this difference, that a much greater fire is necessary for the formation of this latter allay, particularly when the quantity of platina is great. The metal resulting from it has a dark colour, somewhat approaching to a purple or violet, or it easily acquires these colours when exposed to the air. When the two metals fused together are left in a crucible to cool, a considerable part of the platina separates and falls to the bottom, in the same manner as it does from the allay of silver.

From Dr. Lewis's experiments, platina appears to be capable of amalgamating with mercury, but difficultly, and by a very long trituration with water, as for instance, during a week.

If mercury be triturated with an allay of gold and platina, it seizes the gold, and does not touch the platina. Dr. Lewis proposes this amalgamation as a method of separating these two metals; and it is that which is employed with the ores of Peru, in which gold and platina are mixed together: but we do not yet know whether this separation be perfectly complete.

Platina may be allayed with bismuth nearly as with lead, and in a similar manner separates from the bismuth after fusion. It gives to bismuth also, as it does to lead, the property of acquiring, by exposure to air, violet, purple, or blue colours. This allay is always very brittle.

Of all metallic matters zinc may be most easily allayed with platina, and most effectually dissolved by fusion. Dr. Lewis observed, that these allays did not appear very different from pure zinc; but that when the proportion of platina is considerable, their grain is closer, their colour less clear, and more blueish, than that of zinc. They do not tarnish, nor change colours by exposure to air. Lastly, they are harder than zinc, and have not the semi-malleability of this semi-metal.

With regulus of antimony platina formed a darker and harder compound than the pure regulus.

Dr. Lewis has combined platina at the same time with two metallic matters, such as with brass composed of copper and zinc, and with bronze composed of copper and tin. The most singular phenomenon of this latter allay was, that the copper and tin acting conjointly upon the platina were capable of dissolving more of it than they both could do separately. This allay was hard, and capable of receiving a fine polish, but is subject to tarnish, which seems to happen to all the allays of tin or of lead with platina.

Equal parts of platina and brass formed a compound very hard and very brittle, capable of receiving a very fine polish, and not subject to tarnish. It might therefore be employed for speculums of telescopes, and would be much preferable to those now used, all which have the great disadvantage of tarnishing by exposure to air, even very quickly.

Dr. Lewis does not mention the effects of allaying platina with arsenic; but Scheffer affirms, that if only a twentieth part of arsenic be added to platina when red-hot in a crucible, these two substances will be perfectly fused, and will form a brittle gray mass. This remarkable experiment requires confirmation: for Margraaf having also treated these two matters together, did not perceive any such action of arsenic upon platina. From one of his experiments we find, that having exposed to a violent fire during an hour, a mixture of an ounce of platina with a fusible glass, composed of eight ounces of minium, two ounces of  
flints,

flints, and one ounce of white arsenic, he obtained a regulus of platina, well united and fused, which weighed an ounce and thirty-two grains, the surface of which was smooth, white and shining, and the internal parts gray, but which nevertheless appeared sufficiently white when it was filed.

The cupellation of platina was one of the most important experiments to be made; because, if this operation succeeded perfectly, we might thereby obtain compact and malleable masses of pure platina, in the same state as a metal which had been well fused, and of which all sorts of utensils might be made, if not by casting it, at least by forging. All the chemists who have examined this metal, and particularly Dr. Lewis, have used their utmost endeavours to cupel it well. But although they used every expedient to apply the strongest heat, they did not perfectly succeed. The scorification proceeds well at the beginning of the operation, as when gold and silver are cupelled: but the cupellation afterwards becomes more and more difficult; because, as the quantity of lead diminishes, the matter becomes less and less fusible, and at last ceases to be fluid, notwithstanding the most violent heat; and also because, when the quantity of platina is greater than that of the lead, this latter metal is protected, and is not converted into litharge. Hence the regulus obtained is always dark-coloured, rough, adhering to the cupel, brittle, and weighing more than the platina originally employed, from the lead which remains united with it. Messrs. Macquer and Baumé kept the matter exposed to a violent fire during a longer time, that is, about fifty hours successively; therefore, although their platina was tarnished and rough on its surface, it was entirely white and shining, easily separable from the cupel, and a little diminished in weight: a certain proof that no lead remained in it. This platina was also ductile, and capable of extension under the hammer.

The commerce of platina has been prohibited by the Spanish ministry, from an apprehension that it might be employed in the adulteration of gold. Whether this prohibition has since been taken off I know not; but it seems needless, as the mixture of platina greatly alters the obvious qualities of gold, and can be very readily ascertained by the test of sal ammoniac before pointed out.

PLUMBAGO, or black lead, is a well known substance, of a black colour, and shining appearance when cut. Its texture is rather scaly, but its fracture exhibits a granular and dull appearance. None of the specimens have any considerable hardness. This mineral is found in England, Germany, France, Spain, and Africa; but the sort best adapted for making pencils comes chiefly from Borrowdale in Cumberland. For this purpose, it is carefully sawed into narrow slips, or pieces, not more than one-tenth of an inch thick; which are glued between two half cylinders of cedar wood. An inferior kind of pencils is made by the Jews, by mixing the powder or saw-dust with gum arabic, or fusing it with resin or sulphur; and pressing or pouring it into the cavities of reeds. The powder of plumbago, with three times its weight of clay, and some hair, makes an excellent coating for retorts; and the black lead or Hessian crucibles are composed of the same materials.

Plumbago is not subject to alteration by exposure to the action of air or water; and it is insoluble in acids. In closed vessels it is either entirely or nearly unalterable by the strong heat of a furnace; but by continued ignition, and occasional stirring in a shallow vessel, under a muffle, it is gradually dissipated, or burned, leaving a residue of calx of iron, of about one tenth of the original weight. It detonates with nitre in a red heat; ten parts of this salt are required



to one of plumbago before the whole will be decomposed, and exhibit no residue of plumbago when the alkali is dissolved in water. The aerial product of this detonation is found to consist of a mixture of one-third fixed air; and the rest air which maintains combustion: the alkali contains fixed air, and some of the nitre is driven up by the heat. In order to shew that the fixed air came from the plumbago, and not from the nitre, the first analyser \* of this substance detonated tin, antimony, and sulphur, respectively, with nitre, and obtained no fixed air: and, still more to place the inference beyond a doubt, he exposed plumbago to distillation, with twice its weight of dry acid of arsenic: the acid was reduced to the state of white calx, and sublimed; and pure fixed air came over. Similar results were had with the calces of mercury and lead; the metals were revived, and fixed air was expelled. When pulverized plumbago was distilled with caustic fixed alkali by a strong heat, the volatile product was inflammable air; and the remaining alkali contained fixed air.

From these and other facts he concluded, that plumbago is a compound of phlogiston and fixed air, with a little iron, which he supposed to be accidental. The existence of the phlogiston was judged to be proved by its detonation with nitre, as well as by the revival of the acid of arsenic and the metallic calces, and the extrication of inflammable air by alkali: he inferred the quantity of phlogiston in this substance to be twice as much as in charcoal; because it requires twice the quantity of nitre for its detonation. The presence of fixed air was deduced from the aerial products in all the distillations but the last; and from the mild state of the alkalis, in those trials wherein they were used.

The antiphlogistic philosophers † consider plumbago as a compound of iron, and the acidifiable base of fixed air, which they call carbone, because it exists most abundantly in charcoal. The difficulty of burning or decomposing it, is considered as a consequence of the combination of its parts, which are less disposed to unite with vital air than either would be if alone. The same difficulty accounts for the large proportion of nitre required to deflagrate with it completely: a quantity required, not because there is much combustible matter to be burned, but because a long continued and elevated heat is necessary; by which means much of the nitre is decomposed, and its vital air flies off, without having been employed in the combustion, as appears by the two-thirds of the elastic product which will support the flame of a candle. The other facts are easily adapted to this theory. By detonation with nitre it affords fixed air, because the combustible base is acidified by the vital air of the nitre. The arsenical acid, and metallic calces, are reduced by the abstraction of the vital air they contain; which vital air, combining with the acidifiable base contained in the plumbago, converts it into the fixed air, or acid, which flies off: and lastly in the distillation of plumbago with humid alkali, a decomposition of the water takes place: its inflammable air flying off, and its vital air combining with the acidifiable base, as before, forms fixed air, which unites with the alkali, and renders it mild.

The chief difference in the matter of fact between these theorists appears to consist in the iron, which the latter consider as a necessary part of the combination; by means of which they account for its difficult combustibility. Since plumbago does really contain iron, it may be considered as a compound of a similar nature to the martial pyrites. Thus in the pyrites iron is united to sul-

\* Scheele. See his Essays, Eng. Transf. Essay xiii.

† Acad. Par. 1785, page 132 et seq.

phur; which the phlogistian philosophers assert to be a compound of vitriolic acid (or its base) and phlogiston; while their opponents take the sulphur to be a simple substance, capable of acidification by the addition of vital air: and so likewise plumbago is a compound of iron, united to another substance; which the phlogistians assert to be fixed air, combined with phlogiston; at the same time that the other party, rejecting the inflammable principle, affirm that it is the simple acidifiable base, which will form fixed air when vital air is added to it. We see therefore that it is the explanation, and not the facts, which forms the object of contention.

**PLUMBUM CORNEUM.** A combination of calx of lead with marine acid. It is very sparingly soluble in water, and is usually produced by adding marine acid or common salt to a solution of lead in weak nitrous acid.

**POLARITY.** In the experiments of magnetism, it has been found that the attractive and repulsive forces exerted between pieces of iron or steel which have undergone the touch (see **MAGNETISM**), are governed by the position of certain parts of the iron or magnet called its poles. Bodies attracted or repelled by the power of electricity are also observed to turn one side, if at liberty, towards the body which acts upon them. From analogy it is concluded that a similar modification obtains in the effect of the chemical affinities, and is in a great measure the cause of the symmetrical figures of minerals. See **ATTRACTION**, also **CRYSTALLIZATION**.

**POLLEN.** The fecundating powder of the stamina of vegetables. The prolific matter in the male part of plants is elaborated by the anthera; and as the organs of the plant do not admit of an actual intromission of the male into the female, because vegetables do not possess loco-motion, the fecundating seed is produced in the character of a powder, which the agitation of the air and other causes may carry off and precipitate upon the female organs. This fecundating powder has a smell resembling that of the spermatic fluid of animals. It is usually of a resinous nature; that is to say, it is inflammable, and soluble in alkalis and ardent spirit. The wax of bees consists of the pollen very little altered.

**POMPHOLIX.** The white calx which sublimes during the combustion of zinc has been called by this name. It is better known by the name of flowers of zinc.

**PONDEROUS EARTH.** See **EARTH PONDEROUS**, also **SPAR**.

**PONT MARLE.** See **MARLE**.

**PORCELAIN** \* is the most beautiful and the finest of all earthen wares. All earthen wares which are white and semi-transparent are generally called porcelains; but amongst these so great differences may be observed, when they are examined chemically, that, notwithstanding the similarity of their external appearance, they cannot be considered as matters of the same kind. These differences are so evident, that even persons who are not connoisseurs in this way prefer much the porcelain of some countries to that of others.

As the several kinds of porcelain differ so much from each other, no general process can be given for making it. We ought to confine ourselves to describe and consider the manufacture of some particular porcelain, remarkable for its excellence and beauty. But this also is almost impracticable, because in all the manufactories where it is made, both in France and other countries, the ingredients and method of preparation employed are carefully concealed. (See **GLASS**,

\* This article is taken chiefly from Macquer, Weigleb, and Lewis.



p. 352.) The exhibition of a general statement of the principal operations will nevertheless be of value, not only to artists, who very often have no general views of the subjects they pursue, but to philosophical men, who most frequently are the best improvers of manufactories.

The art of making porcelain is one of those in which Europe has been excelled by oriental nations. The first porcelain that was seen in Europe was brought from Japan and China. The whiteness, transparency, fineness, neatness, elegance, and even the magnificence of this pottery, which soon became the ornament of sumptuous tables, did not fail to excite the admiration and industry of Europeans. It would perhaps be a fruitless undertaking to inquire into the history of the several attempts made in Europe to imitate the original porcelain, as most of these are unknown, and would lead us too far from the subject. Macquer is of opinion, that the first European porcelains were made in Saxony and in France; and afterwards in England, Germany, and Italy. But as all these were different from the Japanese, so each of them had its peculiar character.

The illustrious Reaumur first attended to this object among the moderns, and communicated his researches in two Memoirs to the Academy of Sciences in 1727 and 1729. This great experimental philosopher took the best method of arriving at a thorough knowledge of the subject; and although he was mistaken in some points, and neglected to consider some of the essential qualities requisite to constitute good porcelain, he is nevertheless the first person who published any distinct notions upon the subject. He did not satisfy himself with considering the external appearance, the painting and gilding, which are only ornaments not essential to the porcelain, but he endeavoured to examine it internally: and having broken pieces of the Japanese, Saxon, and French porcelains, he examined the difference of their grains (which name is given to their internal structure). The grain of the Japanese porcelain appeared to him to be fine, close, compact, moderately smooth, and somewhat shining. The grain of the Saxon porcelain was found to be still more compact, not granulous, smooth, shining like enamel. Lastly, the porcelain of St. Cloud had a grain much less close and fine than that of Japan, not, or but little shining, and resembling the grain of sugar.

From these first observations he perceived that porcelains differed considerably. That he might examine them further, he exposed them to a violent heat. More essential differences than those of the grain appeared upon this trial; for the Japanese porcelain was unaltered by the fire, and all the European were melted, as Reaumur says.

This essential difference betwixt the Japanese and European porcelains suggested to Reaumur a very ingenious thought, and in many respects true, concerning the nature of porcelain in general. As all porcelains somewhat resemble glasses in consistence and transparency, though they are less compact and much less transparent, this philosopher considered them as semi-vitrifications. Now every substance may appear, and may actually be in a semi-vitrified state in two ways; for, first it may be entirely composed of vitrifiable or fusible matters; and in this case, by exposing it to the action of fire, it will be actually melted or vitrified, if the heat be sufficiently strong and long continued. But as this change is not made instantly, especially when the heat is not very violent, and as it passes through different stages or degrees, which may be more easily observed as the heat is better managed; hence, by stopping in proper time the application of heat to porcelain made in this manner, we may obtain it in an intermediate state betwixt those of crude earths and of completely vitrified substances; and also possessed of

of the semi-transparency and of the other sensible qualities of porcelain. We know also, that if such porcelain be exposed to a stronger degree of fire, it will then be completely fused and entirely vitrified. But most of the European porcelains have this fusibility, from which Reaumur concludes, that their composition is founded upon the above-mentioned principle.

In the second place, a paste of porcelain may be composed of fusible and vitrifiable matter, mixed with a certain proportion of another matter which is absolutely unfusible in the fires of our furnaces. We may easily perceive, that if such a mixture be exposed to a heat sufficient to melt entirely the vitrifiable ingredient, this matter will actually melt; but as it is intermixed with another matter which does not melt, and which consequently preserves its consistency and opacity, the whole must form a compound partly opaque and partly transparent; or rather a semi-transparent mass; that is, a semi-vitrified substance, or porcelain, but of a kind very different from the former; for, as the fusible part of this latter has produced all its effect, and as it has been as much fused as it can be during the baking of the porcelain, the compound may be exposed a second time to a more violent fire, without approaching nearer to a complete vitrification, or without departing from its state of porcelain. But as oriental porcelain has precisely these appearances and properties, Reaumur concludes with reason, that it is composed upon this principle; and he afterwards confirmed his opinion by undeniable facts.

Father Entrecolles, missionary at China, had sent from thence a summary description of the process by which the inhabitants of that country make their porcelain; and also a small quantity of the materials which they employ in its composition. He said that the Chinese composed their porcelain of two ingredients, one of which is a hard stone or rock, called by them petuntse, which they carefully grind to a very fine powder; and the other, called by them kaolin, is a white earthy substance, which they mix intimately with the ground petuntse. Reaumur examined both these matters; and having exposed them separately to a violent fire, he discovered that the petuntse had fused without addition, and that the kaolin had given no sign of fusibility. He afterwards mixed these matters, and formed cakes of them, which by baking were converted into porcelain similar to that of China. Reaumur easily found that the petuntse of the Chinese was a hard stone of the kind called vitrifiable, but much more fusible than any of these which were known in Europe; and that the kaolin was a talky matter reduced to very fine powder. From that time he hoped to make a porcelain of the same kind as the Chinese with materials found in France. Whether he could not find any materials equal to those of China, particularly that material analogous to the petuntse of the Chinese, or because other occupations prevented the continuance of his researches, we do not know; but we find from his second Memoir upon porcelain, that he afterwards attempted to make an artificial petuntse, by mixing our vitrifiable stones with salts capable of rendering them fusible, or even by substituting for it glass ready formed, and by adding to these such substances as he thought might be substituted for kaolin. But he probably found that he could not execute these intentions; for he did not resume this subject from the year 1729 to 1739, when he gave a process for converting common glass to a singular kind of porcelain, to which he has given his name, and of which we shall treat in the following article.

Although Reaumur has not entirely exhausted this subject, he has surmounted many difficulties, and has given just notions concerning it: in a word, he has opened



opened the road for all those who afterwards engaged in this pursuit, and has therefore a right to share the honour of the important discoveries which have been since made by others.

But as a person who first unravels so intricate and hidden a matter as the manufacture of porcelain, can scarcely discover every thing concerning his subject, so Reaumur has been mistaken, or rather misled, in two important particulars, which Macquer points out. His first error concerns the Saxon porcelain, which he confounds with the other fusible porcelains made in Europe. Macquer expresses his doubts whether formerly a porcelain was made in Saxony, composed entirely of fusible or vitrifiable materials, the vitrification of which was stopped in proper time. Possibly this was the first kind of porcelain made in that country, and which Reaumur had examined. He is however certain that he has never seen any such Saxon porcelain, and that all of that country which he had examined was capable of resisting the most violent fires without fusion, as well at least as those of China and Japan. Reaumur might have been misled by the appearance of the internal texture of this porcelain. For when a piece of it is broken, its internal surface does not appear granulous, but compact, uniform, smooth, shining, and much resembling white enamel. But this appearance, so far from shewing that Saxon porcelain is a fused or vitrified substance, proves that it is not entirely composed of fusible matters. All who have considered attentively this subject, know that the internal surface of the most fusible porcelains is also the least dense and least compact; the reason of which is, that no vitreous matter can be smooth and dense internally, unless it has been completely fused. But if the density and shining appearance of the internal surface of the Saxon porcelain were only the effects of the fusion of a vitreous matter, how could we conceive that vessels formed of that matter should have sustained the necessary fusion for giving this density and shining appearance, without having entirely lost their shape? The impossibility of this is evident to every one who has been conversant in these matters, and in the fusion of glass.

This quality of the Saxon porcelain must therefore proceed from another cause. It does indeed contain, as every porcelain does, particularly those of China and Japan, a fusible substance, which has been even completely fused during the baking. Its density also and its internal lustre proceed chiefly from this fused matter; but we are also certain that it contains a large quantity of a substance absolutely unfusible, from which it receives its admirable whiteness, its firmness and solidity during the baking; in a word, which supplies the place of the oriental kaolin, and which has the property of contracting its dimensions considerably while it incorporates with the fusible substance. If it be subjected to the most decisive trial, namely, the action of a violent fire, capable of melting every porcelain composed of fusible matters alone, Macquer affirms, after many experiments, that it cannot be fused, unless by a fire capable of melting the best Japanese porcelain. The Saxon porcelain is therefore not to be confounded with those which are vitreous and fusible, but is in its kind as excellent as that of Japan, and perhaps superior, as we shall see when we enumerate the qualities which constitute the excellence of porcelain. The subject of Reaumur's second error, or, at least, that which he has not sufficiently explained, is the kaolin of China. According to him, this matter is a fine talky powder, from the mixture of which with petuntse the oriental porcelain is formed. Possibly a very finely-ground talky substance mixed with petuntse might form a porcelain similar to the oriental; but persons acquainted with the manufacture of any porcelain must perceive the impossibility

possibility of forming vessels, unless the paste of which they are made be so ductile and tenacious, that it may be worked upon a potter's lathe, or at least that it may be moulded. But talks or any kinds of stones, however finely ground, cannot acquire the requisite tenacity, which clays only, of all known earthy substances, possess. The Chinese porcelain vessels evidently appear to be turned upon the lathe, since they retain the marks of it: hence they must have been formed of a very tenacious paste, and consequently the kaolin is not a purely talky matter, but is mixed with clay; or else the petuntse and kaolin are not, as Reaumur supposes, the only ingredients of the paste of which Chinese porcelain is formed, but a sufficient quantity of some binding matter, unknown to father d'Entrecolles and Reaumur, must be also added.

Although, since Reaumur, no scientific person has written concerning porcelain, many have attempted to make it. Manufactures have been established in almost all the states of Europe. Besides that of Saxony, which has been long established, porcelain is also made at Vienna, at Frankendal, and lately in the neighbourhood of Berlin. All these German porcelains are similar to the Saxon, and are made of materials of the same kind, although they differ somewhat from each other. England and Italy also have their porcelains, the chief of which were those of Chelsea and of Naples. But porcelain is now made of a good quality in Staffordshire, and many other parts of England. M. de la Condamine, in a journey into Italy, visited a manufacture of porcelain established at Florence by the Marquis de Ginori, then governor of Leghorn. M. de la Condamine observed particularly the large size of some pieces of this ware. He says he saw statues and groupes half as large as nature, modelled from some of the finest antiques. The furnaces in which the porcelain was baked were constructed with much art, and lined with bricks made of the porcelain materials. The paste of this porcelain is very beautiful; and from the grain of broken pieces of it, it appears to have all the qualities of the best Chinese porcelain. A whiter glazing would be desirable; which they might probably attain, if the Marquis Ginori had not determined to use those materials only which were found in that country.

But in no state of Europe have more effectual attempts been made to discover porcelain, or an earlier establishment of manufactures, than in France. Before even Reaumur had published on this subject, porcelain was made at St. Cloud, and in the suburb of St. Antoine at Paris, which was of the vitreous and fusible kind, but considerably beautiful. Since that time, considerable manufactures of it have been established at Chantilly, at Villeroy, and at Orleans; the porcelains of which have a distinguished merit. But certainly the admirable works produced in the royal manufacture at Sevres do most honour to France. This porcelain holds at present a distinguished rank, from its shining white, its beautiful glazing, and coloured grounds, in which according to Macquer no porcelain has equalled it. The magnificence of the gilding, the regularity and elegance of its forms, surpass every thing of the kind. In the painting and sculpture much genius and talents are displayed. Lastly, as all the operations of this great establishment were directed by men of known capacity, assisted by philosophical and chemical researches, this manufacture in Macquer's time was upon the point of producing porcelain capable of emulating or equalling the most perfect and most solid works of this kind.

We must carefully distinguish the qualities which only contribute to beauty and external appearance, from the intrinsic and essential properties in which



the goodness and solidity of porcelain consist. All persons who have made experiments in this way have soon discovered the possibility of making compounds very white, beautifully semi-transparent, and covered with a shining glazing, but which cannot be worked for want of tenacity, are not sufficiently compact, are essentially fusible, are subject to break by sudden application of heat and cold; and lastly, the glazing of which cracks, becomes rough, and consequently loses its lustre by use, because it is too soft.

On the other side, we shall also find it not difficult to compose very tenacious pastes, which shall be capable of being easily worked and well baked, which in the baking shall acquire the desirable hardness and density, which are unfusible, and capable of sustaining very well the sudden change of heat and cold; and in a word, which shall have the qualities of the most excellent porcelain, excepting whiteness and beauty. We shall soon see that the materials fit for the composition of such porcelains may be found abundantly in every country. The only difficulty then in this inquiry concerning porcelain is, to unite beauty and goodness in one composition.

Macquer first remarked, that before we had any knowledge of oriental porcelain, and from time immemorial, porcelain was made in Europe equal to it in goodness and in essential qualities, and was universally used, and even sold very cheap. For those potteries called stone-ware are not of modern invention, and have all the essential qualities of the best Japanese. If we except whiteness, on which alone the semi-transparency depends, and compare all the properties of Japanese porcelain with those of our stone-ware, no difference can be found betwixt them. The same grain appears internally in both; the same sound is produced by striking them when properly suspended; the same density, the same hardness, by which they strike fire with steel; the same faculty of sustaining the heat of boiling liquors without breaking, and the same unfusibility in fire, are observable. Lastly, if the earths of which stone-ware is made were free from heterogeneous colouring matters, which prevent their whiteness and semi-transparency; if vessels were carefully formed; if all the proper attentions were given; and if these vessels were covered over with a fine glazing; they would be as perfect porcelain as that of Japan. The most perfect porcelain, therefore, is nothing else than a fine white stone-ware.

The French stone-ware, or potteries de grais, is formed of a whitish clay, in which a good deal of fine white sandy particles is intermixed. The English stone-ware is composed of tobacco-pipe clay and ground flints. This ware, when sufficiently burnt, has, as well as the French, the qualities of porcelain which Macquer calls essential, namely strength, hardness, the property of sustaining the heat of boiling water, and unfusibility. See POTTERY.

Earths of this kind were thought to be more rare in Europe than in Japan and China. And probably also the want of a knowledge where to find these earths was the cause that the first makers of porcelain confined themselves to an external imitation, by employing nothing but vitrifiable matters with fusible salts and a small quantity of white earth, from which fusible and vitreous porcelains were composed, which might be called false porcelains. But things are much changed since these first attempts. Besides the discoveries of the Count de Lauraguais and of Mr. Guettard, genuine white porcelains have been made a long time ago in Germany, especially in Saxony and at Frankendal.

These porcelains are not inferior in any respect to the oriental; they are even much superior in beauty and whiteness to the modern oriental porcelain, which

which has much degenerated in these respects: they seem even to excel the oriental in the most valuable quality of porcelain, namely, the property of sustaining the sudden change of heat and cold. We cannot judge of the quality of porcelain by a slight trial: for so many circumstances concur to make a piece of porcelain capable or incapable of sustaining the sudden application of heat and cold, that if at the same time boiling water be poured into two vessels, one of which is good porcelain and the other bad, the former may possibly break, and the latter remain entire: the only true method of discovering good porcelain in this respect is, to examine several pieces of it which are daily used—for instance, a set of coffee cups. But Macquer says, he has observed that in many such pieces of oriental porcelain, which have been long and daily used, cracks in the direction of their height may be always perceived, which are never seen in the good European porcelains.

Every one talks of porcelain, and yet few are connoisseurs in it. None can be considered as such but those who have long made it an object of their inquiries. That the ancient Japanese porcelain is the most perfect, is a general opinion. This porcelain is indeed very beautiful, and we must also acknowledge that its quality is excellent. It has been our model, and has long been the object of our admiration and emulation; but which we have never been able to equal, and which many persons believe never can be equalled. Some persons even decry the Saxon porcelain for a quality which really gives it a superiority to the Japanese, namely, the greater smoothness, lustre, and less granulous appearance of its internal surface than the oriental. The resemblance of this surface to that of glass has evidently suggested this notion; and it would be well founded, if the density and lustre of this porcelain proceeded only from a fusible and vitreous quality: but as they do not, and as this porcelain is as fixed and as unfusible as the Japanese, its density, so far from being a fault, is a valuable quality. For we must allow, that of porcelains equal in other respects, those are best which are most firm and compact. Hence, the interior substance of the Japanese porcelain is esteemed for its greater density, compactness and lustre, beyond our vitreous or fritt porcelains, because these qualities indicate greater cohesion, and more intimate incorporation of its parts. For the same reason also, the superior density of the Saxon porcelain ought to give it the preference to the Japanese. Besides, nothing would be easier than to give the Saxon porcelain the granulous texture of the Japanese, by mixing with the paste a certain quantity of sand. But the persons who perfected that manufacture were certainly sensible, that such a conformity to the Japanese porcelain would lessen the merit of theirs. For we know that, in general, porcelains are better in proportion as they contain a larger proportion of clay or earth, and less of sand, flints, or other matters of that kind.

The basis of the porcelains which Macquer calls fusible, vitreous, or false porcelains, is called by artists a fritt. It is nothing else than a mixture of sand or of powdered flints, with salts capable of disposing them to fusion, and of giving them a great whiteness by means of a sufficient heat. This fritt is to be then mixed with as much, and no more, of a white tenacious earth, of an argillaceous or marly nature, than is sufficient to make it capable of being worked upon the wheel. The whole mixture is to be well ground together in a mill, and made into a paste, which is to be formed, either upon the wheel or in moulds, into pieces of such forms as are required.

Each of these pieces when dry is to be put into a case made of earthen ware. These cases are called by English potters, *seggars*, which is a corruption of the



the words *safe guard*. They are generally formed of coarser clays, but which must also be capable of sustaining the heat required without fusion. By means of these cases, the contained porcelain is preserved from the smoke of the burning fuel. The whiteness of the porcelain depends much on their compactness of texture, by which the smoke is excluded, and on the purity of the clay of which they are made. These cases are to be ranged in piles one upon another, in a furnace or kiln, which is to be filled with them to the roof. The furnaces are chambers or cavities of various forms and sizes, and are so disposed that their fire-place is placed on the outside, opposite to one or more openings which communicate within the furnace. The flame of the fuel is drawn within the furnace, the air of which rarefying determines a current of air from without inwards, as in all furnaces. At first a very little fire is made, that the furnace may be heated gradually, and is to be increased more and more, till the porcelain is baked, that is, till it has acquired its proper hardness and transparency; which is known by taking out of the furnace from time to time, and examining, small pieces of porcelain, placed for that purpose in cases which have lateral openings. When these pieces shew that the porcelain is sufficiently baked, the fire is no longer to be supplied with fuel, the furnace is to be cooled, and the porcelain taken out, which in this state resembles white marble not having a shining surface. This is afterwards to be given by covering them with a vitreous composition, called the glazing.

The porcelain when baked and not glazed is called biscuit, and is more or less beautiful according to the nature of its composition.

As no imitation of sculpture in porcelain can preserve all the delicacy of its workmanship when covered with a glazing; and as sculptors avoid polishing their marble figures, because the lustre of the polish is disadvantageous; therefore, in superior manufactures, all figures, or little statues, and even some ornamental vases, are left in state of biscuit. The other pieces of porcelain are to be glazed in the following manner:

A glass is first to be composed suited to the nature of the porcelain to which it is to be applied, for every glass is not fit for this purpose. We frequently find that a glass which makes a fine glazing for one porcelain, shall make a very bad glazing for another porcelain, shall crack in many places, shall have no lustre, or shall contain bubbles. The glazing then must be appropriated to each porcelain, that is, to the hardness and density of the ware, and to the ingredients of its composition, &c. Much appears to depend on the glaze, and the body of the ware possessing the property of equally expanding by increase of temperature; if they differ in this respect, the glaze must infallibly crack during the cooling from the furnace.

These glazings are prepared by previously fusing together all the substances of which they consist, so as to form vitreous masses. These masses are to be ground very finely in a mill. This vitreous powder is to be mixed with a sufficient quantity of water, or other proper liquor, so that the mixture shall have the consistence of cream of milk. The pieces of porcelain are to be covered with a thin stratum of this matter, and when very dry they are to be again put into the furnace in the same manner as before, for the forming of the biscuit, and to be continued there till the glazing be well fused. The necessary degree of fire for fusing the glazing is much less than for baking the paste.

The pieces of porcelain which are intended to remain white are now finished; but those which are to be painted and gilded must undergo further operations.

The colours to be applied are the same as those used for enamel painting. They all consist of metallic calxes bruised and incorporated with a very fusible glass. Crocus of iron furnishes a red colour. Cassius's precipitate of gold makes the purple and violet; copper calcined by acids and precipitated by an alkali gives a fine green; zaffic makes the blue; earths slightly ferruginous produce a yellow; and, lastly, brown and black colours are produced by manganese or by calcined iron, together with a deep blue of zaffic. These colours being ground with gum water, or with oil of spike, are to be employed for the painting of the porcelain with designs of flowers and other figures. For gilding, a powder or calx of gold is to be applied in the same manner as the coloured enamels. The painted and gilded porcelains are to be then exposed to a fire capable of fusing the glass with which the metallic colours are mixed. Thus the colours are made to adhere, and at the same time acquire a gloss equal to that of the glazing. The gold alone has not then a shining appearance, which must be afterwards given to it by burnishing with a blood-stone.

The operations for the unfusible porcelains, and also for such as are of the nature of stone-ware, are somewhat more simple. The sands and stones which enter into their composition are to be ground in a mill: the earths or clays are to be washed: the materials are to be well mixed, and formed into a paste: the pieces are first rudely formed upon a potter's wheel; and when dry or half dry, they are turned again upon the wheel, or in a lathe or other engine, and their form is made more perfect: they are then placed in the furnace, not to bake them, but only to apply a sufficient heat to give them such a solidity that they may be handled without breaking, and may receive the glazing. As the pieces of porcelain after this slight heat are very dry, they imbibe water readily. This disposition assists the application of the glazing. The vitrifiable or vitrified matter of this glazing, which has been previously ground in a mill, is to be mixed with such a quantity of water, that the liquor shall have the consistence of milk. The pieces of porcelain are hastily dipped in this liquor, the water of which they imbibe, and thus on their surface is left an uniform covering of the glazing materials. This covering, which ought to be very thin, will very soon become so dry, that it cannot stick to the fingers when the pieces are handled.

The pieces of the porcelain are then put into the furnace to be perfectly baked. The heat is to be raised to such a height, that all within the furnace shall be white, and the cases shall be undistinguishable from the flame. When, by taking out small pieces, the porcelain is known to be sufficiently baked, the fire is discontinued, and the furnace cooled. If the baking has been well performed, the pieces of porcelain will be found by this single operation to be rendered compact, sonorous, close-grained, moderately glossy, and covered externally with a fine glazing. The painting and gilding of this porcelain are to be executed in a manner similar to that already described. For the various compositions of glazes and enamels, see POTTERY.

**PORCELAIN OF REAUMUR.** Reaumur having made many experiments to discover the nature of the materials which enter into the composition of the oriental porcelain, and having ascertained that all porcelain is an intermediate substance betwixt an earth and glass, very ingeniously thought of reducing glass ready made to the state of porcelain, by reversing the effect of the vitrification, or partly unvitriifying it: hence this kind of ware has been called porcelain unvitriified. Reaumur gave the quality of porcelain to glass; that is, he rendered



glass of a milky colour, semi-transparent, so hard as to strike fire with steel, unfusible, and of a fibrous grain, by means of cementation. The process which he published is not difficult. Common glass, such as that of which wine-bottles are made, succeeds best. The glass vessel which is to be converted into porcelain is to be inclosed in a baked earthen case or seggar. The vessel and case are to be filled with a cement composed of equal parts of sand and powdered gypsum or plaster; and the whole is to be put into a potter's kiln, and to remain there during the baking of common earthen ware; after which the glass vessel will be found transformed into such a matter as has been described.

This kind of porcelain has not a very white colour, particularly on its surface; but for some purposes it may be useful, especially for chemical vessels. Reaumur has not explained how this transformation is effected. Macquer imagined that the vitriolic acid of the gypsum quits its basis of calcareous earth, and unites with the alkaline salt and saline earth of the glass, with which it forms a kind of salt or selenites, different from the calcareous selenites, by the interposition of which matter, the glass acquires the qualities of porcelain.

Reaumur says, that glass thus rendered opaque, white, unfusible, and hard, is inferior in beauty to the oriental porcelain; but that in utility and every essential quality of porcelain, it is equal to any, and even superior in the property of sustaining alterations of heat and cold.

The character given by Reaumur of this porcelain induced Dr. Lewis (who had also observed the changes produced upon glass retorts exposed to violent heat in a sand-bath) to make further experiments on this matter, an account of which he has published in the Philosophical Commerce of Arts.

From Dr. Lewis's experiments we find the following results: 1. Green glass cemented with white sand received no change in a heat below ignition. In a low red-heat the change proceeded exceeding slowly; and in a strong red-heat, approaching to whiteness, the thickest pieces of glass bottles were thoroughly converted in the space of three hours. 2. The glass suffered the following progression of changes by continued heat: first, its surface became blue, its transparency was diminished, and a yellowish hue was observable when it was held between the eye and the light. Afterwards it was changed a little way on both sides into a white substance, externally still blueish; and as this change advanced still farther and farther within the glass, the colour of the vitreous part in the middle approached nearer to yellow: the white coat was of a fine fibrous texture, and the fibres were disposed nearly parallel to one another, and transverse to the thickness of the piece: by degrees the glass became throughout white and fibrous, the external blueishness at the same time going off, and being succeeded by a dull whitish or dun colour: by a still longer continuance in the fire, the fibres were changed gradually from the external to the internal part, and converted into grains; and the texture then was not unlike that of common porcelain. The grains, at first fine, and somewhat glossy, appeared afterwards larger and duller, and at length the substance of the glass became porous and friable, like a mass of white sand slightly coherent. 3. Concerning the qualities of the converted glass Dr. Lewis observes, that the whiteness of the internal part was not inferior to that of porcelain, but that its surface was the least beautiful, that the thick pieces were quite opaque, and that several thin pieces were semi-transparent; that while it remained in a fibrous state, its hardness became greater than that of glass, or of the common kinds of porcelain; it was capable of sustaining sudden

sudden changes of heat and cold better than any porcelain; and in a moderate white heat, it was fusible into a substance not fibrous, but vitreous and smooth, like white enamel: that when its texture had become coarsely granulated, it was now much softer and unfusible: and lastly, that when some coarsely granulated unfusible pieces, which with the combination of a moderate heat would have become porous and friable, were suddenly exposed to an intense fire, they were rendered remarkably more compact than before; the solidity of some of them being superior to that of any other ware. 4. No difference appeared in the internal colour, hardness, texture, or the regular succession of changes, from the use of different cementing substances; though in external appearances the differences were considerable. All the pieces which had been surrounded with charcoal or with soot, were externally of a deep black colour, which did not disappear by exposure to a strong fire during an hour, with free access of air. Coloured clays and sands communicated different shades of a brown colour; and white earths gave whitish, grayish, or brownish tinges. White sand, calcined flints, and gypsum, gave in general the greatest whiteness, and tobacco pipe clay the greatest glossiness and brightness. 5. Glasses composed of earths without alkaline salt, glass of lead, flint glass, crown-glass, looking-glass plates, a glass prepared with calcined flints and a fixed alkaline salt, and even green glass which had been fused together with a ninth part of alkaline salt, suffered none of the above alterations by cementation. Green bottle-glass and common window-glass were most susceptible of these alterations. 6. The changes produced by cementation could not proceed from any absorption of matter from the cementing substance, because no increase of weight was given, and because the same changes were produced upon a piece of glass merely by heat, without any cementing substance.

Dr. Lewis in his reflections on this subject refers the change to a loss of part of the alkali of the glass. The weight of the fibrous porcelain is not perceptibly different from that of the glass itself; but he observes, that the alkali which may exude is attached to the outer surface; and in the latter stages of the process, it evidently causes an agglutination of the sand in which the glass may be bedded. M. Delaval, who has made many experiments on this object, shewed me a mass of sand concreted in the form of the neck of a bottle, out of which he had poured the sand of the glass itself reduced to perfect grains by the heat. It seems probable in this instance, that the sand of cementation had a greater affinity to the alkali than that of the glass itself.

**PORPHYRY.** Porphyrites. The porfido of the Italians. Cronstedt enumerates five kinds: 1. Green, with a light green felt-spar. *Serpentino verde antico*. It is said to have been brought from Egypt to Rome, from which last place the specimens now come. 2. Deep red with white felt-spar from Italy and Eger in Norway. 3. Black with white and red felt-spar from Klitten in the parish of Elfdalen in Norway. 4. Reddish-brown with light red and white felt-spar; and 5. Dark gray with white grains of felt-spar. The dark red porphyry has been most frequently employed for ornaments and in building.

De Saussure and Kirwan, quoted by Magellan, both reckon under the name of porphyry or porfido of the Italians, such stones as contain either felt-spar, quartz, shoerl, mica, with other species of stone of a crystalline form in a siliceous or even calcareous ground. Ferber, in his sixteenth letter from Italy, describes twenty varieties of porfido. But in general it is distinguished by the colour



lour of its ground, that is, either red, purple, gray, green, or black. When the ground is of jasper the porfido is very hard. The red commonly contains felt-spar in small white dots or specks, and often together with these black spots of shoerl. The green is either a jasper or shoerl with spots of quartz. It is often magnetic. Sometimes a porphyry of one colour contains a fragment of porphyry of another colour. Those which have chert for their ground are fusible without addition. The calcareous porphyry consists of quartz, felt-spar, and mica, in separate grains united by a calcareous cement. And the micaceous porphyry consists of a greenish-gray micaceous ground, in which red felt-spar and greenish soap-rock are contained.

**PORTLAND STONE.** A compact sand-stone from the Isle of Portland. The cement is calcareous.

**POTASH.** It is universally known \* that the vegetable fixed alkali may be extracted in greater or less quantity from the roots of almost all vegetables, and it is now well established, that it pre-exists in vegetables before combustion, not indeed in a separate uncombined state, but united partly with the vitriolic and marine acids, and sometimes the nitrous, but generally, and for the greater part, with a vegetable acid and oil, with which it forms essential salts, as they are termed. These vegetable acids and oils are decomposed during combustion, and thus the alkaline part is set free. But the vitriolic acid by contact with inflamed matter, is converted into sulphur, part of which unites to the disengaged alkali, which protects it from combustion, and forms what is called liver of sulphur; a product formed in most ashes, especially when the air has not had free access to them during combustion.

As alkaline salts are of great importance in the several arts, the proportion of ashes afforded by different vegetables, and that of alkali by each vegetable has of late been accurately attended to. Kirwan has therefore presented the best authenticated results of the experiments made with this view.

<i>One thousand lbs.</i>	<i>lbs. of ashes.</i>	<i>lbs. of salt.</i>
Stalks of Turkey wheat or mais	88,6	17,5
Sun-flowers	57,2	20,
Vine-branches	34,	5,5
Box	29,	2,26
Sallow	28,	2,85
Elm	23,5	3,9
Oak	13,5	1,5
Aspen	12,2	0,74
Beech	5,8	1,27
Fir	3,4	0,45
Fern in August	36,46	4,25
Wormwood	97,44	73,
Fumitory	219,	79,

\* This article is taken from Kirwan's excellent and useful paper on the alkalis in the Irish Transactions for 1789.

*Table of the saline product of one thousand lbs. of ashes of the following vegetables.*

<i>Saline products.</i>		
Stalks of Turkey wheat or mais	—	198 lbs.
Stalks of Sun-flower	—	349
Vine branches	—	162,6
Elm	—	166
Box	—	78
Sallow	—	102
Oak	—	111
Aspen	—	61
Beach	—	219
Fir	—	132
Fern cut in August	—	116 or 125 according to Wildenheim
Wormwood	—	748
Fumitory	—	360
Heath	—	115 Wildenheim.

On these tables Kirwan makes the following remarks:

1. That in general, weeds yield more ashes, and their ashes much more salt, than woods; and that consequently, as to salts of the vegetable alkali kind, as pot-ash, pearl-ash, cashup, &c. neither America, Trieste, nor the northern countries have any advantage over us (Ireland).

2. That of all weeds, fumitory produces most salt, and next to it wormwood. But if we attend only to the quantity of salt in a given weight of ashes, the ashes of wormwood contain most. *Trifolium fibrinum* also produces more ashes and salt than fern.

Most of the experiments on woods were made in France by order of government, under the inspection of the overseers of the salt-petre works; yet are to be read with caution by those who attend to the quantity of alkali with respect to bleachers. For as tartar vitriolate, a salt useless to bleachers, is as serviceable to the makers of salt-petre as alkaline salts\*, they have constantly confounded one with the other; but the experiments made on weeds were instituted by persons who carefully discriminated these salts. One hundred grains of the salt of wormwood contain but six of the tartar vitriolate, and one hundred grains of the salt of fumitory contain fifteen. All alkaline salts, unless mixed with lime, contain also one fifth at least of fixed air, which produces no other effect in bleaching than that of restraining their activity.

The process for obtaining pot and pearl ash is given by Kirwan, as follows:

1. The weeds should be cut just before they seed, then spread, well dried, and gathered clean.
2. They should be burned within doors on a grate, and the ashes laid in a chest as fast as they are produced. If any charcoal be visible, it should be picked out, and thrown back into the fire. If the weeds be moist, much coal will be found. A close smothered fire, which has been recommended by some, is very prejudicial.
3. They should be lixiviated with twelve times their weight of boiling water.

\* Much of the nitre obtained by elixation of the nitre beds has a calcareous basis. Tartar vitriolate will change this into prismatic nitre by double affinity. For the alkali unites with the nitrous acid, which gives its calcareous base to the vitriolic. N.



A drop of the solution of corrosive sublimate will immediately discover when the water ceases to take up any more alkali. The earthy matter that remains is said to be a good manure for clayey soils.

4. The ley thus formed should be evaporated to dryness in iron pans. Two or three at least of these should be used, and the ley, as fast as it is concreted, passed from the one to the other. Thus, much time is saved, as weak leys evaporate more quickly than the stronger. The salt thus procured is of a dark colour, and contains much extractive matter, and being formed in iron pots is called pot-ash.

5. This salt should then be carried to a reverberatory furnace, in which the extractive matter is burnt off, and much of the water dissipated: hence it generally loses from ten to fifteen per cent. of its weight. Particular care should be taken to prevent its melting, as the extractive matter would not then be perfectly consumed, and the alkali would form such an union with the earthy parts as could not easily be dissolved. Kirwan adds this caution, because Dr. Lewis and Mr. Dossie have inadvertently directed the contrary. This salt thus refined is called pearl-ash, and must be the same as the Dantzic pearl-ash.

The French call the refined ash *potasse*, and the unrefined *salin*. Kirwan remarks, that the alkali manufactured in the above-mentioned manner may not be sufficiently caustic for the earlier operations of bleaching; but by the addition of half a pound of quick-lime to every hundred of the salt, or ten pounds for every ton, it will be rendered sufficiently sharp. There is no danger that any of the lime will remain in the ley; but if any should, it will immediately be discovered and deposited by the addition of a little of the unmixed ley.

For the most economical construction of a laboratory and furnaces for the above operations, Kirwan refers to the description given in a French tract called *L'Art de fabriquer le Salin et la Potasse*; which I have not seen. And he adds, that it would be no inconsiderable advantage to perform the evaporation by a fire made of vegetables, whose ashes might afterwards be employed. Pearl-ash, as he also remarks, is frequently tinged green or blue, not from any union of the salt with phlogiston, as was formerly imagined, but from manganese, which Scheele has shewn to exist in the ashes of most vegetables. When the alkali is calcined without melting, it proves perfectly white, like the Dantzic pearl-ash.

POT-STONE. See LAPIS OLLARIS.

POTTER'S LEAD ORE. The galena or combination of lead and sulphur.

POTTERY. \* The art of making pottery is intimately connected with chemistry, not only from the great use made of earthen vessels by chemists, but also because all the processes of this art, and the means of perfecting it, are dependent on chemistry. We must however acknowledge, that although chemists have the greatest interest to procure good crucibles and other earthen vessels, this art has been left almost entirely to the potter. Mr. Pott is the first who attended to this object. Besides many experiments stated in his *Lithogegnosia*, from which much instruction may be received relating to the perfection of chemical vessels, he has written a treatise expressly on this subject, in which he gives many compositions for crucibles, the chief of which shall be mentioned in this article.

All kinds of pottery are in general made of clays or argillaceous earths, because these earths are capable of being kneaded, and easily receiving any form,

\* The general part of this article is from Macquer,

and of acquiring much solidity and hardness by exposure to fire. But clays differ much in the effects produced upon them by fire. Some clays which are of the purest kind resist the most violent fire without receiving any other change than a considerable hardness; but still they are not rendered so hard and compact as other clays. A second kind of clays by exposure to violent heat acquires a hardness equal to that of flints, and a texture compact and glossy, like that of good porcelain; but they are nevertheless unfusible by the most violent heat. These qualities are occasioned by some fusible materials being mixed with them, as sand, chalk, gypsum, or ferruginous earth, which are in too small a quantity to effect a complete, but only a beginning or partial fusion. Lastly, a third kind of clays is first hardened by fire, and afterwards completely fused. This last kind of clays evidently contains the largest quantity of the fusible matters above mentioned.

From the properties of these three principal clays it may be concluded, that from clays alone three principal kinds of pottery may be produced. With the first kind of clay, pots or crucibles may be formed capable of sustaining the most violent fire without fusion, of containing melted metals, and even hard glasses not too fluid; but which, from want of sufficient compactness, are incapable of containing during a long time in fusion very fusible substances, such as nitre, glass of lead, glasses containing much arsenic, &c. by which substances their pores are pervaded. These clays are employed advantageously for the formation of large pots or crucibles used in glass-houses for containing hard glass, as bottle-glass.

With clays of the second kind may be made crucibles and other potteries, commonly called stone-ware. Potteries made with these earths, when sufficiently baked, are very sonorous, so hard as to strike fire with steel, capable of containing all liquids, of which the former kind, from their porosity, are incapable, and even resist the action of nitre, glass of lead, and other fluxes, when the earth of which they are formed is of good quality: but their hardness and density, which prevent their sudden expansion and contraction, by the hasty application of heat and cold, make them liable to break in all operations where they are suddenly exposed to heat or to cold, as for instance, in a furnace through which a strong current of air passes. If this kind of pottery had not this inconvenience, it would be the best and most perfect for the purposes of ordinary life and chemistry. Notwithstanding this inconvenience, it is the only pottery that is applicable on many occasions; but then all possible care must be taken to prevent its breaking, by a very gradual application of heat and cold, and by protecting it from currents of cold air.

With the fusible clays may be made many kinds of vessels, which are cheap, as they require little fire to bake them; for all this kind of pottery is but slightly baked; whence its texture is coarse and porous. Some utensils are made of this pottery without glazing, as foot-stoves, &c. But in general they are covered with a glazing, without which, water or other liquids would pass through their pores. Some of this pottery, which is finished with more care, is covered with a white enamel, which makes it very neat and like porcelain. This is called **DEFT WARE**, which see. Other coarser potteries of this kind are glazed with glass of lead mixed with metallic calxes, or fusible coloured earths; from which they receive various colours. This is the ordinary pottery.

A fine kind of pottery is made of white clays, or of such as whiten in the fire, the surface of which is vitrified by throwing into the furnace, when the ware is



sufficiently baked, some common salt and salt-petre. This pottery is called English ware on the continent, because the first and best was made in England. It is white, fine, well baked, and has some small degree of transparency when thin; so that it is intermediate betwixt porcelain and common stone-ware, and may therefore be called a semi-porcelain.

Keir affirms, that he has never seen any English stone-ware, that had the semi-transparency and whiteness mentioned by Macquer. As the English stone-ware is composed of tobacco pipe clay and ground flints, both which substances are perfectly unfusible, singly or jointly, it cannot possess any degree of transparency. The use of the flints is to give strength to the ware, so that it shall preserve its form during the baking: whereas vessels made of clay alone, though unfusible by fire, and capable of acquiring, by having been exposed to an intense heat, the hardness of the best porcelain; yet while they are hot and soft, they sink by their own weight, so as to lose the form given them. The process of manufacturing this stone-ware, according to Dr. Watson, is as follows:

Tobacco-pipe clay from Dorsetshire is beat much in water: by this process, the finer parts of the clay remain suspended in the water, whilst the coarser sand and other impurities fall to the bottom. The thick liquid, consisting of water and the finer parts of the clay, is farther purified by passing it through hair and lawn sieves of different degrees of fineness. After this, the liquid is mixed (in various proportions for various wares) with another liquor, of as nearly as may be the same density, and consisting of flints calcined, ground and suspended in water. The mixture is then dried in a kiln; and being afterwards beaten to a proper temper, it becomes fit for being formed at the wheel into dishes, plates, bowls, &c. When this ware is to be put into the furnace to be baked, the several pieces of it are placed in the cases made of clay, called seggars, which are piled one upon another, in the dome of the furnace: a fire is then lighted; and when the ware is brought to a proper temper, which happens in about 48 hours, it is glazed by common salt. The salt is thrown into the furnace, through holes in the upper part of it, by the heat of which it is instantly converted into a thick vapour; which circulating through the furnace, enters the seggar through holes made in its side (the top being covered to prevent the salt from falling on the ware), and attaching itself to the surface of the ware, it forms that vitreous coat upon the surface, which is called its glaze.

This curious method of glazing earthen ware by the vapour of common salt was introduced into England by two Dutchmen, near a century ago. It appears to be produced by a combination of the alkali with the siliceous earth or sand of the clay.

The yellow or Queen's ware is made of the same materials as the flint-ware; but the proportion in which the materials are mixed is not the same, nor is the ware glazed in the same way. The flint-ware is generally made of four measures of liquid flint, and of eighteen of liquid clay; the yellow ware has a greater proportion of clay in it; in some manufactories they mix 20, and in others 24 measures of clay with four of flint. These proportions, if estimated by the weight of the materials, would probably give for the flint-ware about three cwt. of clay to one cwt. of flint, and for the yellow ware somewhat more clay. The proportion, however, for both sorts of ware depends very much upon the nature of the clay, which is very variable even in the same pit. Hence a previous trial must be made of the quality of the clay, by burning a kiln of the ware. If there is too much

much flint mixed with the clay, the ware, when exposed to the air after burning, is apt to crack; and if there is too little, the ware will not receive the proper glaze from the circulation of the salt vapour.

This glaze, even when it is most perfect, is in appearance less beautiful than the glaze on the yellow ware.

The yellow glaze is made by mixing together in water, till it becomes as thick as cream, 112lb. of white lead, 24lb. of ground flint, and 6lb. of ground flint glass. Some manufactories leave out the glass, and mix only 80lb. of white lead with 20lb. of ground flint: and others doubtless observe different rules, of which it is very difficult to obtain an account.

The ware before it is glazed is baked in the fire: by this means it acquires the property of strongly imbibing moisture; it is therefore dipped in the liquid glaze, and suddenly taken out; the glaze is imbibed into its pores, and the ware presently becomes dry. It is then exposed a second time to the fire, by which means the glaze it has imbibed is melted, and a thin glassy coat is formed upon its surface: the colour of this coat is more or less yellow, according as a greater or less proportion of lead has been used. The lead is principally instrumental in producing the glaze, as well as in giving it the yellow colour; for lead, of all the substances hitherto known, has the greatest power of promoting the vitrification of the substances with which it is mixed. The flint serves to give a consistence to the lead during the time of its vitrification, and to hinder it from becoming too fluid, and running down the sides of the ware, and thereby leaving them unglazed.

The yellowish colour which lead gives when vitrified with flints may be wholly changed by very small additions of other mineral substances. Thus, to give one instance, the beautiful black glaze, which is fixed on one sort of the ware made at Nottingham, is composed of 21 parts, by weight, of white lead, of five of powdered flints, and of three of manganese. The Queen's ware at present made is much whiter than formerly.

The coarse stone ware made at Bristol consists of tobacco-pipe clay and sand, and is glazed by the vapour of salt, like Staffordshire flint-ware; but it is far inferior to it in beauty.

Chaptal tried various methods to glaze pottery, and two among them succeeded well enough in his opinion to justify his publishing them. The first consists in mixing the earth of Murviel, which appears to be a fusible or compound clay, in water, and dipping the pottery therein: this done, they are suffered to dry; after which they are plunged into a second water, in which levigated green glass is mixed. This covering of vitreous powder fuses with the clay of Murviel, and the result is a very smooth, very white, and very cheap glazing.

The second method consists in immersing the dried pottery into a strong solution of sea salt, and afterwards baking them. The trial which Chaptal made in his furnaces gave him reason to expect that this method might be used in large works.

He likewise obtained a very black glazing by exposing pottery strongly heated to the fumes of sea-coal. He coated several vessels in this manner by throwing a large quantity of coal in powder into a furnace, wherein the pottery was ignited to whiteness. The effect, he informs us, is still more complete, when the chimneys or tubes of aspiration of the furnace are at that moment closed, and kept so for some minutes.

Some potteries can sustain a sudden application of heat and cold sufficiently



well for the uses of a kitchen, and are therefore called fire-ware; but these are always the coarsest, least baked, and the glazing of which is the softest. They also do not last long when much used; for it is absurd to suppose, as some persons do, that pottery may be made capable of sustaining fire like a metal vessel. We are certain, that the best of this kind which are employed for this purpose, break as soon as they are put upon the fire. They do not indeed break so as to separate in pieces, or even to let liquors pass through them; but many small cracks are formed, which we may be assured of by the crackling heard upon their being first set on the fire, by the many cracks which may be perceived in their glazing, and by their ceasing to ring when struck, after they have been once heated. Each time that these vessels are set on the fire, many small imperceptible cracks are formed in them, which by frequent use become so numerous, that the vessel may be broken by the least force. Thus all the difference betwixt the potteries which are intended to be used on the fire, and the good stone-ware which is not intended for that purpose, is, that this latter kind may be broken at once, when heated and cooled carelessly, whereas the former is broken by degrees. Nevertheless the fire-ware is useful, as it can serve for a short time.

Tobacco-pipes require a very fine, tenacious, and refractory clay, which is either naturally of a perfectly white colour, or, if it have somewhat of a gray cast, will necessarily burn white. A clay of this kind must absolutely contain no calcareous or ferruginous earth, and must likewise be carefully deprived of any sand it may contain, by washing. It ought to possess, besides, the capital property of shrinking but little in the fire. If it should not prove sufficiently ductile, it may be meliorated, by the admixture of another sort. Last of all, it is beaten, kneaded, ground, washed and sifted, till it acquires the requisite degree of fineness and ductility.

When after this preparation the clay has obtained a due degree of ductility, it is rolled out in small portions to the usual length of a pipe, perforated with a wire, and put, together with the wire, into a brass mould rubbed over with oil, to give it its external form; after which it is fixed in a vice, and the hollow part of the head formed with a stopper. The pipes thus brought into form are cleared of the redundant clay that adheres to the seams, a rim or border is made round the head, they are then marked with an iron stamp upon the heel, and their surfaces smoothed and polished. When they are well dried, they are put into boxes and baked in a furnace. In the Dutch manufactories, these boxes consist of conical pots made of clay, with conical lids, with a tube passing through the middle of them, by which the pipes are supported; or else they are long clay boxes, in which the pipes are laid horizontally, and stratified with fragments of pipes pounded small.

Lastly, the pipes, when baked, are covered with a glazing or varnish, and afterwards rubbed with a cloth. This glazing consists of a quarter of a pound of soap, two ounces of white wax, and one ounce of gum-arabic or tragacanth, which are all boiled together in five pints of water for the space of a few minutes.

All the operations where great heat is employed require vessels of baked earth; because these alone can sustain at once the action of violent fire and of chemical solvents. Vessels made of good baked clay eminently possess these two qualities, and are the best which can be employed in chemistry; but as they have the inconvenience of breaking by sudden application of heat and cold, and as many operations do not require vessels so dense, mixtures of earth have been used,

used, of which crucibles are made, capable of being rendered suddenly red-hot, and suddenly cooled without breaking, and sufficiently dense to contain metals and other matters in fusion during a long time. The best crucibles of this kind are brought from Hesse in Germany. These crucibles are made with a good refractory clay, mixed, according to Pott, with two parts of sand of a middling fineness, from which the finest part has been sifted. The mixture of sand with clay produces two good effects; the first, to make the clay leaner, as it is called, and thus to prevent the clay from cracking by the contraction it sustains during its drying; and secondly, to prevent its acquiring too great closeness and compactness of texture by being baked. Thus we obtain crucibles moderately dense, capable of containing metals and other things in fusion, and infinitely less subject to break by heat and cold than those made of pure clay.

The particles of the sand mixed with clay in this composition for crucibles ought to be rather of a moderate size than very fine; because, as Pott remarks, the former renders the crucibles much less apt to crack than the latter. In the second place, that chemist forbids the use of sand, flints, or other earths of that kind, in the composition of crucibles intended to contain glasses or vitrifying matters a long time in fusion; because these vitreous matters act upon sand, flints, and all those called vitrifiable earths; by which means these crucibles are soon penetrated and melted.

This inconvenience is prevented, and all the advantages obtained from a mixture of sand are procured, by substituting to the sand a good baked clay in gross powder. In this manner are made the pots which contain the vitrifiable materials in glass-house furnaces, some of which resist the continued fires employed there during three weeks or a month. The pots indeed used in glass-houses frequently sustain a constant fire during several months, and sometimes even a year. They become gradually more and more thin, the glass or flux contained probably dissolving them thus slowly.

The quantity of burnt clay in the composition for crucibles varies in proportion to the nature of the crude clay from 1, 2, 2½, or even three parts of the former, to one of the latter. In general, the stronger, more tenacious and compact the crude clay is, the larger quantity of burnt clay ought to be mixed with it.

The crucibles made in France are composed on the same principles. They are made of clay mixed with broken butter-pots, which are a stone-ware made in Normandy and Picardy. These crucibles resist admirably well sudden heat and cold, and they would be excellent if the crude clay which enters into their composition was capable of resisting a violent fire: but this clay being mixed with martial and pyritous matters swells in the fire, and begins to melt. Besides, these crucibles owe their good quality of not breaking by sudden application of heat and cold to their little density, which is attended with this inconvenience, that they are penetrable by very fluid matters.

We may from what has been said perceive the difficulty, perhaps the impossibility, of making perfect crucibles. Pott has made so many experiments on this subject, that he seems to have exhausted it. The basis of all his compositions was clay; but this he mixed in different proportions with metallic calxes, calcined bones, calcareous stones, talks, amianthus, asbestos, pumice-stones, tripoli, and many others, from none of which did he obtain a perfect composition, as may be seen from his Dissertation: hence it may be concluded, that we must have in our laboratories crucibles of different kinds suitable to the several operations:

Paris.



Paris crucibles, when the matters contained are not too fluid, and the fire is not too strong; Hessian crucibles, when similar matters are to be exposed to a violent heat; and crucibles of baked clay, for vitrescent matters and penetrating fluxes.

Crucibles may possibly be made better than any hitherto known, and of more extensive use. The essential point is, to obtain a very refractory clay free from pyritous matter and ferruginous earth, from which the sand must be washed. This must be mixed with two or three parts of the same clay baked and pounded grossly; and of this mixture or paste crucibles must be formed in moulds, and baked in a very strong fire. As retorts and cucurbits are designed for the distillation of liquors generally very corrosive and penetrating, they ought to be made of stone-ware.

To the above observations on crucibles, which are extracted from Macquer's Dictionary, I shall add some farther extracts made by Keir from Pott's Dissertation above quoted.

1. Crucibles made of fat clays are more apt to crack, when suddenly exposed to heat, than those made of lean or meagre clays. Meagre clays are those in which a considerable quantity of sand is mixed with the pure argillaceous earth, and fat clays are those which contain but a small proportion of sand.
2. Some crucibles become porous by long exposure to fire, and imbibe part of the contained metals. This inconvenience is prevented by glazing the internal and external surfaces, which may be done by moistening these with oil of tartar, or by strewing upon them, when wetted with water, powdered glass of borax. These glazings are not capable of containing glass of lead.
3. Crucibles made of burnt clay grossly powdered, together with unburnt clay, were much less liable to crack by heat than crucibles made of the same materials, but in which the burnt clay was finely powdered, or than crucibles made entirely of unburnt clay.
4. If the quantity of unburnt clay be too great, the crucible will be apt to crack in the fire. Crucibles made of ten ounces of unburnt clay, ten ounces of grossly powdered burnt clay, and three drams of calcined vitriol, are capable of retaining melted metals, but are pervaded by glass of lead. The following composition is as good or better than the preceding: Seven ounces of unburnt clay, fourteen ounces of grossly powdered burnt clay, and one dram of calx of vitriol. These crucibles may be rendered more capable of containing glass of lead, by lining their internal surfaces, before they are baked, with burnt clay diluted with water. They may be further strengthened by making them thicker than is usually done, or by covering their external surfaces with some unburnt clay, which is called arming them.
5. The composition, of which crucibles the most capable of containing glass of lead were made, was eighteen parts of grossly powdered burnt clay, as much unburnt clay, and one part of fusible spar. These crucibles must not, however, be exposed too suddenly to a violent heat.
6. Crucibles capable of containing very well glass of lead, were made of twenty-four parts of unburnt clay, four parts of burnt clay, and one part of chalk. These required to be armed.
7. Plume-alum powdered, and mixed with whites of eggs and water, being applied to the internal surface of a Hessian crucible, rendered it capable of containing glass of lead during a long time.
8. One part of clay and two parts of Spanish chalk made good crucibles. The substance called Spanish chalk is not a calcareous earth, but appears to be a steatites.
9. Two parts of Spanish chalk and one part of powdered tobacco-pipes made a good composition for lining common crucibles.
10. Eight parts of Spanish chalk, as much burnt

burnt clay, and one part of litharge, made solid crucibles. 11. Crucibles made of black lead are fitter than Hessian crucibles for the melting of metals; but they are so porous, that fused salts pass entirely through them. They are more tenacious than Hessian crucibles, are not so apt to burst in pieces, and are more durable. 12. Crucibles placed with their bottoms upwards are less apt to be cracked during the baking than when placed differently. 13. The paste of which crucibles are made ought not to be too moist, else when dried and baked they will not be sufficiently compact: hence they ought not to be so moist as to be capable of being worked on a potter's lathe, but they must be formed in brass or wooden moulds. See Pott's Dissertation on Chemical Vessels.

Scheffer says, that the best crucibles cannot easily contain metals dissolved by sulphur, in the operation of parting by means of sulphur. See PARTING. He says, that they may be made much more durable and solid, by steeping them a few days in linseed oil, and strewing powdered borax upon them before they are dried. Mem. Sued. xiv. 1752.

**POWDER.** This word signifies precisely the same thing in chemistry as it does in common life. Any solid matter divided into small particles not adherent to each other forms a powder. When any substance is pulverised, the number of surfaces or quantity of surface in the whole will obviously be greater the finer the powder. Various contrivances are in daily use to pulverise different bodies. The pestle and mortar is used in the operation of pounding. The circulation of two mill-stones against each other, with grooves cut in the face of each to admit the subject of action, is used in the operation of grinding. By an hard smooth stone rubbed on the face of another, also smooth, trituration is effected; for which purpose water or some other fluid is added to the substance to be triturated. And lastly, washing is used to separate the smaller particles of powder from the larger or heavier; whether the latter be chiefly wanted, as in mine-works, or the former, as in washing emery and other fretting powders.

Several chemical and a still greater number of medical preparations are known by the name of powders.

**POWDER OF ALGAROTH.** This preparation is also called emetic powder, or mercurius vitæ. It is produced by adding water to the butter of antimony, and is a white calx of the semi-metal. In doses from three to four grains it is violently emetic and purgative; but inconstant in its effects, as are all the preparations of antimony which are not in the saline state. Modern medical practice has rejected it.

**POWDER, GUN.** See GUN-POWDER. This powder is well made when it explodes with a bright clear flame, and does not soil the plane on which it is burned. It is also reckoned a good criterion, when a number of small separate heaps of powder are laid at a small distance from each other, and one being fired does not set fire to the rest; because this can only be done by small grains of powder or coal being thrown at a distance before they are completely burned. Such powder must therefore be slow and weak in its action. But the real force is best ascertained from the mechanical effect. This is measured by filling a small instrument or pistol called the powder proof, and firing it. The explosion drives the index of a wheel through a greater or less number of divisions, as the powder is stronger or weaker. Other instruments more easily compared with each other have been made, in which the explosion from a gun drives upwards a plug or piston loaded with an heavy weight, to heights which vary with the force. But



the description of these is in some measure foreign to the general objects of chemical science.

The analysis of the chemist cannot shew whether the parts of gunpowder be intimately mixed as they ought to be to give it all its force, nor whether the saline matter has been partly separated, or the coal rendered less inflammable by damp in the keeping. But it is nevertheless on many accounts desirable and necessary to know the component parts of particular parcels of this substance. For this purpose the nitre may be extracted by boiling in water, and its quantity ascertained by evaporation and crystallization, or otherwise by drying and weighing the residue, which is the charcoal and sulphur. From this residue the sulphur may be burned off on a metallic plate by a gentle heat sufficient only to make it smoke by day-light. The remainder will be the charcoal.

Robins, in his Principles of Gunnery, has shewn that the force of the hot elastic fluid extricated by the explosion of gunpowder is nearly equal to a thousand times the pressure of the atmosphere. This force is seldom applied to any of the arts of peace, on account of the expence.

**POWDER FULMINATING.** See **FULMINATION.**

**PRASE.** A blueish chrysolite. See **PRECIOUS STONES**, No. V.

**PRECIOUS STONES.** Under this article I shall collect the general properties and facts relating to the precious stones, in addition to the shorter notices to be found under their respective titles\*.

Stones which are highly prized for their external appearance, and on that account denominated precious, are, 1. Diamond. 2. Ruby. 3. Sapphire. 4. Topaz. 5. Chrysolite. 6. Beryl. 7. Emerald. 8. Hyacinth. 9. Amethyst. 10. Garnet. 11. Tourmalin. 12. Opal. And of inferior note are, 13. Rock Crystal. 14. Cats Eye. 15. Hydrophanes or Oculus Mundi. 16. Chalcedony. 17. Moon Stone. 18. Onyx. 19. Carnelian. 20. Sardonyx. 21. Agates; and 22. The Labradore Stone.

**I. The DIAMOND.** The chief mines of diamonds are in the Asiatic Peninsula on this side of the Ganges, towards the Gatte mountains, not only at Golconda, but in many other parts, as Coulour, Raolconda, Bisnagar, Neustafanagar, Parreal, Latawar, Soumalpour and Malacca; some of which are now exhausted: besides these, diamonds are found in the island of Borneo; and above all in Brasil, in the province of Serra do Frio, in the place called Cay de Marin, near the river Milho-Verde. See Bomare's Mineralogy, vol. i. and Romé de l'Isle's Cristallographie, vol. ii. As to the soil or mine in which diamonds are found, M. Bomare says, that they are sometimes found stuck to rocks, and in clusters like rock-crystals; but this seems to be very seldom the case. Tavernier says (page 327 of his second volume), that they are found in a sandy earth, and in the loose earth that fills the clefts of some rocks. That their mines at Gani, otherwise called Coulour, where six thousand people were at work, are in a marshy ground. At Soumalpour the diamonds are found in the bed of the river Gouel, whose waters are turned with great labour into another channel for this purpose: and Engestrom says he was informed by very good authority, that the Brazilian mines of diamonds are worked in the same manner. At Borneo it is also in the river Succadan that diamonds are found, according to the same Taver-

\* I have chiefly availed myself of the second edition of Cronstedt's Mineralogy, and the authors quoted by Magellan in his valuable Notes.

nier. But what this famous traveller says of certain diamonds which have a greenish crust, is very remarkable. These green diamonds burst into pieces, either whilst they are in working to receive a proper figure, or when in the act of being polished on the wheel: and he mentions a large diamond, bought by a Jew named Edward, for which 25 thousand piastres (about 500 pounds sterling) had been offered when brought to Leghorn, that on being sent to Venice, in order to be cut there, burst into nine pieces whilst polishing on the wheel. This conveys, it seems, the idea of some similarity between diamonds and the lachryma Batavica, which may perhaps be extended to all hard crystallizations like those of gems. See GLASS.

The specific gravity of diamonds, according to Wallerius, is from 3,100 to 3,400: Hauksbee judges it to be 3,666: Ellicot, 3,519: Briffon, 3,5212.

Diamonds commonly crystallize into octoedral forms, which however are often found somewhat irregular, especially when the surface inclines to crystallize, during the shooting of the whole crystal, and also when several of them unite together into a group; in which latter circumstance the one hinders the other from assuming its regular form. But the octoedral is not the only regular form which the diamond assumes. Engestrom mentions a rough diamond in its native state, in a regular cube, with its angles truncated or cut off.

Diamonds of a dodecaedral form are not uncommon: those of Malacca are rhomboidal and cubic: and some have been found of fourteen sides or planes.

The substance of diamonds is lamellated, consisting of very thin plates like those of talc, but extremely hard and intimately united, the direction of which the lapidary must discover, not only to cleave the ill-shaped diamonds, but to cut and shape them properly. This last operation is performed by rubbing a diamond with another till it has the required figure. It is afterwards polished upon an horizontal wheel of steel, employing the same powder that falls from their rubbings, with common olive oil. Such diamonds as have an irregular grain like the knots of wood cannot well be shaped: and lapidaries call them diamonds of nature. See Bomare's Mineralogy, p. 393, vol. i. The art of cutting diamonds was invented in 1476, by Louis de Berquen, a native of Bruges in the Austrian Netherlands.

Jeffries, in his Treatise on Diamonds, asserts very positively, that, upon the strictest examination, there is not least difference between the best oriental and Brazilian diamonds. It is nevertheless asserted that some of the latter are not combustible.

There are diamonds of all colours, though not deeply so, viz. some incline to the rose colour, others to green, blue, brown, black: and some have black specks. Tavernier saw one of this last kind weighing about 56 carats in the treasury of the Mogul; he says also, that the mines of Carnatica produce yellow and black diamonds: and Mr. Dutens says (page 13 of his Treatise) that he saw a black diamond at Vienna, in the collection of the Prince de Lichtenstein.

The diamond becomes phosphoric, either by being exposed to the solar rays, or by being made red hot in a crucible on the fire. When rubbed it becomes electric, and attracts small pieces of straw, paper, feathers, hairs of animals, silk, &c. M. D'Arcet found, not only that diamonds included in porcelain crucibles close, or covered with perforated lids, and exposed to the long and intense heat of a porcelain furnace, were perfectly dissipated; but also, that this stone could in a few hours be totally volatilized with a much inferior degree of heat, by exposing it in a coppel under the muffle of an essay-furnace. In this latter experiment,



he observed, that the dissipation was gradual, and that it was effected by a kind of exfoliation. The dissipation of diamonds exposed in coppels was confirmed by Macquer, who further observed, that the diamonds were, before the dissipation began, rendered by the fire brilliant and shining, as it were with a phosphoric light. In order to determine whether the dissipation of diamonds was actually effected by their reduction into vapour, or by a combustion or other effect of air upon them, Messrs. Lavoisier, Macquer and Cadet exposed diamonds to intense heat in an earthen retort during several hours, but without any other effect than that their polish was destroyed, and about  $\frac{1}{7}$  of their weight diminished. M. Mitouard put diamonds in a tobacco-pipe filled with pounded charcoal and accurately closed with lute. He further secured the diamonds from access of air or flame, by placing the tobacco-pipe in a crucible to which another crucible was inverted and carefully luted. The diamonds thus secluded from external air having been exposed to the most intense heat which could be excited in a well constructed furnace, were not thereby altered or diminished. M. Mitouard was induced to believe, that the charcoal conducted to the preservation of diamonds not merely by excluding the air, but by some peculiar property, which he supposes may be the same as that by which this substance defends metals from destruction by fire. He was confirmed in his opinion by observing that diamonds, were not preserved from the action of fire by surrounding them with powder of chalk, and of calcined hartshorn, and including them in close vessels, so well as when the charcoal had been employed. Some chemists even thought that the perfect exclusion of air alone was sufficient to preserve diamonds, and doubted whether the balls and crucibles of porcelain employed by M. D'Arcet had excluded the air with sufficient accuracy. Indeed, in one of M. D'Arcet's own experiments, a diamond included in a ball of porcelain had resisted the action of fire. In order to ascertain this question, M. Cadet exposed diamonds in covered and luted crucibles to the violent heat of a forge during two hours; by which operation the diamonds lost only  $\frac{1}{10}$  part of their weight. He infers that the destruction of diamonds by fire in open vessels is not a true volatilization, but merely an exfoliation, caused by the fire expanding the air contained between the thin plates of which these stones consist, and that by this exfoliation or decrepitation these plates are reduced to so fine a powder as to escape observation. M. D'Arcet objected against the experiments of his adversaries, that they were not of sufficient duration to decide against his, which had lasted several days. He renewed and multiplied his experiments, which confirmed him in his opinion of the volatilization of diamonds in vessels perfectly closed; and that this effect of fire on diamonds is not a mere exfoliation or mechanical separation of the plates of which these stones consist, he infers from the parts of the diamonds pervading the most solid porcelain crucibles without being perceptible, and from the luminous appearance first noticed by M. Macquer, and which was afterwards observed by M. Roux to be an actual flame. Some beautiful experiments have been lately made at Prague on the combustion of diamonds. (*Annales de Chimie*, for November 1791.) To the diamond which is to be burned is fastened a piece of iron wire, which is then made red hot, and plunged into a jar containing dephlogisticated air. The fire from the iron wire spreads to the diamond, which burns with the greatest vividness. Some diamonds, such for instance as those which come from Brazil, cannot be made to burn by this treatment. On account of the dearness of these substances, the experiments have not yet been carried to any great length; but Mr. Landriani hopes to prevail upon the Emperor to have them repeated,

repeated, with a view to ascertain the quantity and quality of the residues, the alteration which the air in which they are burned undergoes, and the cause of the great difference in the qualities of diamonds. For the value of diamonds, see DIAMONDS.

The jargon has been considered as a soft diamond, but is very different in its nature. See JARGON.

II. The RUBY. Red ruby. *Adamas ruber*. *Rubinus*. The ruby was formerly considered as of the same kind with the diamond; but latter experiments shew how widely diamonds differ from any other gems by their constituent parts.

According to Tavernier, vol. ii. p. 356, and Dutens, p. 23, all coloured hard stones are called rubies in the East Indian mines, adding to each its different colour for distinction sake; but there are also some soft stones of this kind which they call *bacan*: and Wallerius, as well as Romé de l'Isle, rightly asserts that the oriental (the hard and brilliant) rubies, sapphires and topazes are the very same stone, the colour excepted. It is certain that they have the same form, and some are partly red, and partly blue, yellow, or quite colourless. As to their colour, it proceeds from the martial mixture which enters into their composition. Rubies are found in the Capelan mountain of Pegu, at Chaos Ava, Bishnagar, Calicut, Cananor, Ceilan and Brasil. They are found in the sands of rivers of a red colour, in an argillaceous earth of a hard texture, and of a greenish colour; and sometimes they are adherent to red rocks.

Tavernier speaks of 108 rubies in the Mogul's throne, from 100 to 200 carats, and of a round one of almost two ounces and a half: and Robert de Berquen speaks of one of 244, another of 123, and another of 209 carats.

Of rubies, according to Cronstedt, there are four kinds. 1. The ruby of a deep red colour, inclining a little to purple. This is the *carbunculus* of Pliny; but all red gems were so called by the ancients. Those of a deeper colour are called *almandini*, according to Wallerius; and the jewellers call this the oriental ruby on account of its hardness and brilliancy. By the experiments of M. D'Arcet the ruby does not lose its colour in the greatest fire: but Henckel, by means of a burning glass, softened it so as to receive the impression of a seal of jasper. This ruby is the hardest gem after the diamond; and being rubbed becomes electric.

Its specific gravity, according to Bergman, is from 3,180 to 4,240. According to Briffon, it is = 4,283.

Its texture is foliated like that of the diamond: it is fusible with borax in a violent and long continued heat; and forms a transparent glass of a pale green: it does the same with microcosmic salt: but with sedative salt, or mineral or vegetable alkali, the glass is opaque and of various colours. See the various experiments of Messrs. Bergman and Achard on this kind of gems.

A perfect ruby above  $3\frac{1}{2}$  carats weight, according to Dutens, is more valuable than a diamond equally heavy: if it weighs one carat, it is worth 10 guineas; if two carats 40 guineas; if three carats, 150 guineas; if six carats, above 1000 guineas.

2. The spinell ruby of a ponceau red, that is, of a bright corn-poppay-flower colour.

Romé de l'Isle from Briffon acquaints us, that the form of this ruby is octoedra: its specific gravity is 3,760, of that from Brasil 3,531.

These rubies are found in Hungary, Silesia, Bohemia, and some in Brasil according



according to Bomare and R. de l'Isle. Their value, according to Dutens, is reckoned at the half of diamonds of the same weight.

Rubies are artificially made from topazes of Brasil, of a smoky appearance, by giving them a gradual heat in a crucible filled with ashes, until it is red-hot. See R. de l'Isle and Dutens, who quote the History of the Royal Academy of Sciences of Paris for the year 1747. It was Dunielle, a jeweller, who communicated this secret to Mr. Guetard of the Royal Academy of Sciences at Paris.

3. The balafs-ruby, pale red inclining to violet. This is supposed to be the mother of rubies: it comes chiefly from Brasil, although some come likewise from the East Indies. The value of the balafs-ruby is at the rate of thirty shillings per carat. Dut.

4. The rubicell, of a reddish colour. But authors do not agree in the characters of these stones.

They come also from Brasil, but it is said that their colour is lost in the fire: if so, they must be of a different nature from the Brazilian topaz, which gets a red colour from fire, as has been already observed.

The rubino di rocca of the Italians, or rubinus rupium, according to Bomare, is a true garnet, of a deep red and violet, or of the amethyst colour. What is called ruby of arsenic, or of sulphur, is the realgar: the ruby of zinc is the red blend: and the ruby of silver is the red silver ore, &c.

III. The SAPPHIRE. Sapphirus gemma. It is transparent, of a blue colour, and is said to be the hardest next to the ruby, or diamond.

The sapphires in their rough and native state crystallize most generally in two oblong hexagonal pyramids pointed at their tops, and joined at their basis: yet they are sometimes found of an hexagonal columnar form. In the fire they lose their blue colour.

Engestrom informs us, that he has found some of the deep blue sapphires, and some of a milky colour, which, when looked through, varied their colours in the same manner as the milky blueish opals. This is however no reason why those opals should be marked under the name of sapphire, and less so since there are also agates found of the same quality. This might rather give rise to a question, whether the name of milky or blueish opal is not to be considered as a vague term, since that principal quality is found in stones of a somewhat different nature, though they all belong to the flinty order.

Sapphires are said to be found in Alsatia, at St. Amarin; but accounts of this kind are in general not to be depended upon, as the fluors are frequently met with in collections and in the druggists' shops under the name of sapphires, when they are of a deep blue colour; not to mention that the quartz is always termed a precious stone, whenever it is found clear and of a fine colour. The sapphire is said to lose its blue colour in the fire. Those which are but little tinged, are called white sapphires. The sapphire is seldom found of a very deep blue colour, and free from parallel flaws which run through it.

The fine hard sapphires, or, as jewellers call them, the oriental ones, are according to Engestrom of the same kind as the ruby and the topaz, their colour excepted.

The late King of France, as we are informed by R. de l'Isle and R. de Berquin, had one with a yellow stripe of a fine topaz in the middle. Some are found half green and half red. This substance is foliated like the ruby; those from Puy in Auvergne seem to approach to the true sapphire, by their form and specific gravity; but they lose both their colour and transparency by fire, and become

black and even vitrify, according to R. de l'Isle, which proves that they are of a different kind.

It is said that sapphires lose their colour by fire, and remain so hard and transparent as to pass sometimes for diamonds. But Mr. Achard found that they are not altered in the least by fire, in colour, hardness, or weight: however, these circumstances may not be common to all sapphires.

According to Bergman, the sapphire is the third in hardness, the ruby being the hardest of all after the diamond: and according to R. de l'Isle it becomes electric by being rubbed. Its name was taken from *Σαπφειρ*, the place where they were found, according to Lemery, quoted by Bomare. But it is evident, says Engestrom, from Pliny (lib. 37. cap. 9.), that the sapphire of the ancients was our lapis lazuli.

Its specific gravity, according to Bergman, is from 3650 to 3940; but according to R. de l'Isle the oriental is = 3,994: the Brazilian = 3,1307: and that from Puy = 4,0769. The sapphire when powdered is fusible with borax, or with microcosmic salt, into a transparent glass, as well as with magnesia alba. Bergman and Achard found nearly the same results from the analysis of this gem.

They are found in the same place as rubies: and those called occidental, are also formed in Siberia, Bohemia, Alsace, and Auvergne. Romé de l'Isle speaks of one of this last place, which was entirely green or blue, according to the side it was looked through.

Dutens informs us, that a good sapphire of 10 carats is valued at 50 guineas. If it weighs 20 carats, its value is 200 guineas; but under two carats it may be valued by multiplying the carat at 10s. 6d. into the square of its weight.

Sapphires are preferable to common rubies, for jewelling the pallets of escape-ments, and the holes of wheel-pivots, in astronomical watches and clocks, on account of the homogeneous hardness of their substance: because there are red stones which are called rubies, but are not uniformly hard.

IV. The TOPAZ. *Topazius gemma*. According to Pliny (lib. 37. cap. 8.), this gem took its name from an island in the Red Sea, where it was first found; but it is evident from his words that it was some kind of lapis ollaris, fusible spat, or other kind of stone of a greenish-yellow cast, that the ancients called topaz; since he speaks of a topaz of a greenish colour, and four cubits large, viz. above six English feet (= 68,476 French inches = 72,978 English inches), which cannot be applied either to our topaz or to our chrysolite, as some pretend. It appears, however, from the following chapter of the same author, that our topaz was called chrysolite by the ancients, as its name indicates: but what he says of one Bocchus, who had seen one of those gems of 12 Roman pounds weight, or 10,78 pounds troy, is not incredible; since there is now a rough topaz in the Prince's cabinet at the Hague, of the shape of an egg, that is upwards of seven inches in length, and must consequently weigh considerably more than the above. This topaz, which I saw many years ago, has the appearance of a pebble rounded by water. Its surface and colour resembled rosin. A considerable piece had been broken from one end, where the fracture appears vitreous and the stone clear. I suppose it must have been from trials with this piece, that its claim to the character of a topaz was ascertained.

The topaz, when rough and perfect, is sold in a crystallized form. At Schneckenstein in Saxony, these crystals are found of a prismatical octoedral form, with no points, but flat, and with some facets at the top; perhaps the oriental topazes have another figure.

Engestrom



Engestrom mentions some rough Brazil topazes, which were in his possession, and were prismatical, and of a rhomboidal quadrangular figure, pointed at one end. It is very likely, that these, as well as many other crystals, may be pointed at both ends, when nothing has interrupted their crystallization.

He mentions, besides these, some fragments of other topazes in his possession, which were likewise said to be from the Brazils, all which were prismatical, but plainly shewed that some are pentagonal, and others regular hexagons with points.

The topazes lose their colour in the fire; but some of them turn red in a certain degree of heat, and are therefore very much used instead of the pale rubies, and even are often sold as such.

According to R. de l'Isle and Dutens, the topaz is of a lamellated structure, like the other gems: it is the third in hardness after the diamond, and on being rubbed becomes electric. Its form is prismatic of six or eight sides, ending in two quadrangular pyramids. Some are striated, some are of a rhomboidal figure, and some are even of a cubic form.

Their specific gravity is from 3,460 to 4,560, according to Bergman; but according to Briffon it is equal to 4,0106: and R. de l'Isle informs us that those of Brazil = 3,5365.

The topaz appears white when reduced to powder, melts easily with borax and lime; and when calcined is considerably altered, loses its colour, and acquires weight.

The best topazes are called oriental: they have the same properties as rubies and sapphires, the colour excepted. They are found in Pegu, Ceylon, Arabia, Egypt, and Brazil.

Those called occidental lose their colour, transparency, and hardness in the fire. The topazes from Saxony, though they are as hard as the oriental, agree with the occidental in their other properties.

Experiments by fire have been made on the Schneckenstein topazes by Mr. Pott, as may be seen in his *Lithogegnesia*. The rock of Schneckenstein in the valley of Danneberg in Voigtland of the Upper Saxony, is about 80 feet high, and about three times as much in its base: it is as hard as the topazes themselves, and its powder is employed in polishing them.

But we have some topazes from Brazil, whose substance is widely different, as they do not lose their transparency nor hardness by fire; but even turn red like a fine ruby, and are sold as such. Those from Bohemia are in large prisms: their colour inclines to the hyacinth: and some are colourless, as is the case with some sapphires.

Tavernier speaks of a very fine topaz belonging to the Mogul, of  $157\frac{1}{2}$  carats: and many others are known of a very large size.

The oriental topaz is valued by multiplying the square of its weight in carats into 15 or 16 shillings; and the occidental one at the rate of five or six shillings.

To the Schneckenstein topaz Cronstedt refers, 1. The pale yellow topaz, which is almost colourless, and is found at Schneckenstein. 2. The yellow topaz from Schneckenstein. 3. The deep yellow, or gold-coloured topaz, which is the oriental topaz; and 4. The orange-coloured topaz.

V. The CHRYSOLITE. See the article.

VI. The BERYL. This is a blueish-green topaz, which varies in its colours, and is called, when of a sea-green colour, the aqua marina, but when more green the beryl.

According to R. de l'Isle the aqua marina found by Pallas in the mountain Adontscholo of Siberia, the Peru emerald, and the chrysolite from Brazil, are nearly the same, both in their form and in their specific gravity. Briffon says, that this last of the Siberian aqua marina is 2,7213. According to Sage, quoted by R. de l'Isle, it does not vitrify in the fire, but becomes opaque, and cracks in its surface.

The great Saxon mineralogist, and superintendant of the mines, M. Pabst von Oheim, who has a very instructive collection, likewise possesses such an octoedral aqua marina, on a piece of quartz druse from Schneckenstein, growing among some yellow topazes. It has no points, and the whole crystal has a flaw across the prism.

Mr. Dutens informs us, that the beryl and aqua marina are transparent, and of a green blue colour: some jewellers erroneously call them by the name of oriental coralina. They come from Ceylan, from the shores of Euphrates, from the neighbourhood of mount Taurus, and from Brazil.

Beryls are found in the stream-works in Saxony and Bohemia, in the form of pebbles, or round pieces.

VII. The EMERALD. Lat. *Smaragdus gemma*. Swed. and Germ. *Smaragd*. Fr. *Emerhaude*.

The Romans called it the Neronian or Domitian gem. The Persians and Indians call it pachac: and the Arabians zamarrut, from whence it is supposed the word *smaragdus* is derived.

According to R. de l'Isle, the oriental emerald is a true sapphire of a green colour.

The chief colour of the emerald is green, and it is transparent. In their rough or native state, emeralds consist of hexagonal columns, mostly truncated at both ends. Engestrom informs us, that he had samples of both transparent grass-green and light green colours, which in a gentle heat became colourless; but white and opaque in a strong fire, without the least mark of any fusion.

The same author observes, that when crystallized cockle or shirl is found of a green colour, transparent, and free from cracks or flaws, it is commonly called emerald by the jewellers, though it is generally of a deeper colour than the true emeralds, and also wants their lustre; and hence it is, that the cockle spar from Egypt is called the mother of emeralds. However it may be, this cockle was in ancient times fashionable in Egypt, under the name of emerald, though at present it is not so much valued as the emerald of this (siliceous) kind.

Crönstedt is of opinion that the emerald is, or has been, a crystal of its own separate principle, since in its qualities it differs both from the above-mentioned and from the rock crystal. This however he says he cannot positively assert, as he knows no more of it, than that it is the softest of precious stones, and that when heated it is phosphorescent like the fluors.

According to Wallerius, the emerald, when heated to a white heat, becomes of a deep blue, and phosphorescent. It however recovers its green colour when cold. When pulverized it becomes white; and melts with-borax to a very thin colourless glass.

Romé de l'Isle says, that it becomes electric by being rubbed.

Its specific gravity, according to Wallerius, is 2,700, or 2,800. Briffon makes it 2,7755: and Bergman from 2,780 to 3,711.

Of emeralds there are two kinds. 1. The pale green emerald, which comes from the east and from Peru. According to Brunnich, the figure of these emeralds is an hexagonal truncated prism. Their basis is a vein of white quartz.

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The finest druse or cluster of this kind is to be seen at Loretto in the treasure of the Holy Chapel near Ancona, consisting of more than 100 great and small emeralds. A fellow to it is made by art, and both are presents of the King of the two Sicilies, to represent two Mount Calvaries.

2. The dark green emerald. These are columnar, and striped longitudinally; their colour is very dark, and they are hardly transparent. The points are generally broken off, though Davilla mentions one in form of a blunted triangular pyramid. There is one with a five-sided pyramid in the Imperial cabinet at Vienna. Some of them, which must be selected by trials, have the properties of the tourmalin, of attracting ashes, when they are laid on burning coals, and acquire a certain degree of heat; but Brunnich says, he never could discover that they repelled them again.

They do not attract so strongly as the tourmalin. The Prince of Noja, in his letter on the tourmalin, mentions the Brazilian emeralds among those hard stones, which, when they are put into the fire, receive no electric power like the tourmalin: but he was possessed of, and tried, such as really had not that quality. The celebrated inspector of the Austrian mines, M. Jacquin, was a witness to the experiments of Brunnich.

That which in some cabinets is exhibited as the matrix of the emerald, and said to come from Egypt, is nothing but a deep green cockle spar, of which colour we likewise find cockle, or whirl, in the island of Uto near Stockholm, and at Norberg, in the province of Westmanland.

Mr. Maillet informs us, that in former times the best emeralds were found in Egypt.

Pliny mentions (lib. 37. c. 5.) twelve kinds of emeralds: but from his words it clearly appears that many of these were different green stones, so called by the ancients. Theophrastus says (page 65 of Hill's edition), that in the records of the Egyptian kings, mention is made of an emerald four cubits long, and three broad: and of an obelisk composed of four emeralds, which was 40 cubits long, and from four to two cubits wide. Each Egyptian cubit, according to Pausan, is equal to  $10\frac{2}{3}$  French inches, or near 11 English inches. If these and like accounts of large emeralds are to be depended upon, we must think they were some sparry fluors like those we have in Derbyshire, or some green glasses, like those manufactured in England, which are as beautiful as the true emeralds: and of this kind seems to be that large one kept in the Abbey of Reichenau near the Lake of Constance, mentioned by Romé de l'Isle, page 246, vol. ii. of his Crystallography, which measures above two feet and a half in length.

VIII. The HYACINTH. To the precious stones belong also the jacinths, or hyacinths, which are crystals harder than quartz crystals, transparent, and of a fine reddish-yellow colour when in their full lustre.

The best hyacinths come from Arabia, Calicut and Cambaya. According to R. de l'Isle and Dutens, they only differ in colour from rubies. They are called oriental, when very hard and brilliant; and they are then reckoned among topazes: but when they are soft, they belong to the garnet kind: those from Compostella in Spain are of this last sort.

According to Dutens, the specific gravity of this gem is 2,631: but Romé de l'Isle says that Brisson found it be 3,6873; and those of Europe 3,760.

Hyacinths are formed in prisms pointed at both ends; these points are always regular, with respect to the number of the facets, being four on each point, but the facets seldom tarry: the sides also which form the main body, or column,  
are

are very uncertain, both as to their number and shape; for they are found of four, five, six, seven, and sometimes of eight sides: and besides this, the column or prism is in some so compressed, as almost to resemble the face of a spherical faceted garnet.

According to R. de l'Isle, they are of a dodecaedral form, like the garnet, but their angles are more obtuse.

R. de l'Isle and Dutens inform us, that the *jacinta la bella* of the Italians is a garnet of this yellowish hue: but when it is more of a reddish colour, it is then called *vermeille* by the French.

According to Mr. Dutens too, the *chrysolestre* is a yellow-brown hyacinth, like honey, or amber, but very distinct from the above two by being less hard, and by not having any electric power.

These crystals lose their colour, become white, and do not melt in the fire; by which qualities chiefly they may be distinguished from garnets, which are likewise sometimes found of a colour not inferior to the true jacinths. The reddish-yellow garnets from Greenland are sold by the jewellers for jacinths; so are likewise the East Indian garnets of the same colour; and, what is still more, there are some jewellers that do not know the true distinctions between a jacinth and a garnet at all, but buy and sell the garnets for jacinths, when they are of a fine reddish-yellow colour: this must in particular be owing to the scarcity of the true jacinth.

Cronstedt had some jacinths in his possession of a quadrangular figure, which did not melt in the fire, but only became colourless. This confirms what has been already mentioned about the jacinths above described.

IX. The AMETHYST. The amethysts called occidental are of the same nature as rock crystals, and have the same gradations, viz. of a violet inclining to the purple or rosy colour, or inclining to the blue. They are very often semi-transparent without any colour in one end, and violet towards the other. The best are found in the Vic mountains of Catalonia in Spain, and at Wiefenthal in Saxony, as well as in Bohemia, in Germany, in Italy, and in the province of Auvergne in France.

Crystals within the geodes, or hollow agate, are, according to R. de l'Isle, very often found of an amethyst colour, and some are very fine.

What is now called amethyst root, or mother of amethyst, is but a sparry fluor, of which there are plenty in Derbyshire. Many fine ornamental pieces are made of this substance in different forms and shapes. These spars are found in insulated masses, sometimes pretty large, but never in the form of large rocks.

X. The GARNET. Lat. *Granatus*. Swed. *Aesta* or *Klar Granat*. French, *Granat*. Germ. *Echter* or *Klarer Granat*. See GARNET.

The garnets of Bohemia, according to Cotes, have a specific gravity of 4,360; and those of Sweden, according to the same author, 3,978.

Their colour proceeds from the iron which enters into their composition; and M. de Sauffure asserts, that even the finest oriental garnets attract the magnetic needle at a small distance.

The Syrian garnet is the finest and most esteemed. It is of a fine red inclining to the purple colour, very diaphanous, but less brilliant than the oriental amethyst. It seems to be the *amethystizontas* of Pliny: the Italians call it *rubino di rocca*, and it is found in Syria, Calicut, Cananor, Camboya, and Ethiopia.

The fine garnet of a red inclining to a yellow colour is the *foranus* of the ancients, the *vermeille* of the French; and the *giacinto guarnacino* of the Italians.



Its name is taken from Sorian, or Surian, a capital town of Pegu, from whence these gems are brought: when they have a brownish tint, they are then called hyacinths.

The occidental garnet is of a deep and dark red, and its hardness is less. However, some very fine hard garnets are found in Bohemia. Garnets are found also in Hungary, at Pyrna in Silesia, at S. Sapho in the canton of Berne, in Spain, and in Norway.

The garnet melts in the focus of a good burning glass into a brown mass, which is attracted by the loadstone, and this shews that iron enters considerably into its composition.

Some garnets are found which contain a little gold. Those called zingraupen by the Germans contain tin.

Magellan thinks it probable, that the lapis alabandicus of Pliny (lib. 36. c. 8.) which was black, and that other which he mentions of a deep purple (lib. 37. c. 7.) among the gems, were both true garnets.

XI. The TOURMALIN. Ashdrawer. Tourmalinus, lapis electricus. Trip in Germ.

This is a kind of hard stone, lately brought into notice by its electrical properties.

This stone has been known in Europe since the year 1717 only, in which year Lemery first shewed it in the Royal Academy of Sciences at Paris. Since that time it has been made more known: and the Dutch have spread it every where. Most of them are flat on one side, and convex and polished on the other. There are, however, likewise some rough ones like pebbles. Most of them are transparent: and the Prince de Noja, in his letter to Count Buffon, affirms, that he likewise had an opaque one. Brunnich informs us, that the largest he ever saw is in the cabinet of Mr. Steiglitz at Leipzig: its size is nearly a square inch, and its thickness two lines. Besides this size it has a very remarkable quality. When you look through the two largest surfaces, which are but two lines asunder, it appears wholly opaque; but covering these, and looking through the small surfaces which are near twelve lines asunder, it is quite pellucid, which is supposed to arise from the peculiar texture of the stone, but may be owing to a want of polish or opacity at the larger surfaces. It is flat on one side only. We know nothing of the spot where the tourmalin is generated. Äpin and Bergman have written the latest dissertations upon it, and mentioned all its electric qualities. Dr. Pallas shewed Brunnich a tourmalin, which was perfectly like the others in colour, hardness and transparency, but would not draw ashes. Wilson affirms, that when a tourmalin is made red hot, and kept in a violent fire for half an hour, it does not lose its colour; but if it be cooled of a sudden in water, it loses its electric quality for ever.

The form of the tourmalin is a prism of nine sides of different breadth, mostly truncated, and seldom terminating in a pyramid at each end, which is either composed of three pentagons, or of nine triangles.

When heated in the fire, it gives signs of contrary electricity on the two opposite ends of its prismatic form. See Priestley's Electricity.

Professor Bergman found several opaque schoerls of Sweden to possess the same electric qualities of the tourmalin, but could not find any pellucid ones with the same property.

Many of these stones are not in the least electric. However, on being rubbed, they become electric in their sides, like other diaphanous gems.

They are almost as hard as the topaz, and strike fire with steel.

They melt by themselves in a strong fire, though with difficulty.

With the microcosmic salt they melt perfectly; but only in part with borax.

With mineral alkali, they are divided into a kind of powder.

The three mineral acids dissolve them, when first reduced to a powder.

They bear a greater similarity to schoerls than to any other stone: but their component parts shew that they may be ranged with propriety in this place, along with other precious stones: as the argillaceous earth is also the most prevalent in their composition.

The oriental tourmalins are found in the island of Ceylon. They are transparent, of a dark brown-yellow: and their specific gravity is from 3,062 to 3,295.

Those from Brazil are transparent, and for the most part green; but there are also some red, blue and yellow; their specific gravity is from 3,075 to 3,180.

Those from Tyrol are of so dark a green as to appear opaque. Their specific gravity is about 3,050. These are found in beds of steatites and lapis ollaris among the micaceous veins, talcs, and hornblende of Schneeberg, Jurzagl, and Zillerthal, in the mountains of Tyrol.

Those from the mountains of Old Castile in Spain are transparent, and have the same properties as the preceding.

XII. The OPAL. See OPAL.

XIII. ROCK CRYSTAL. See CRYSTAL ROCK, also QUARTZ.

XIV. The CAT'S EYE. See the article.

XV. The HYDROPHANES, or OCULUS MUNDI. See HYDROPHANES.

XVI. The CHALCEDONY. See the article.

XVII. The MOON STONE. Ditto.

XVIII. The ONYX. Ditto.

XIX. The CARNELION. Ditto.

XX. The SARDONYX. This is a mixture of the chalcedony and carnelion, sometimes stratum-wise, and sometimes confusedly blended, or mixed together.

Of this stone there are two kinds. 1. That which is striped with white and red strata: this serves as well to cut in cameo, as the onyx. 2. The white with red dendritical figures. This very much resembles that agate which is called the mocha-stone, but with this difference, that the figures are of a red colour in this, instead of black, as in the mocha-stone.

According to Cronstedt, there is no real difference between the onyx, carnelion, chalcedony, sardonyx and agate, except in some inexplicable degree of hardness.

XXI. The AGATE. This name is given to flints which are variegated with different colours, promiscuously blended together; and they are esteemed in proportion to their mixture of colours, their beauty and elegance. Hence also they have obtained a variety of names, most of which are from the Greek.

Near the bridge over the Mulda, not far from Freyberg in Saxony, a red and white agate breaks in veins. This is called coral-stone in Italy. The agate of Rochlitz in Saxony is the most celebrated, and is found in globules which have a kind of crust about them.

As it ever was, and must be very difficult to give intelligible descriptions of colours, we are for that reason quite at a loss to understand the meaning of the ancients in this respect; but, indeed, it is of little consequence, as we seem to



have the same right, under the same circumstances, of inventing new names for them; and that in whatever languages we please. The following is a description of some few varieties of those which at present are the most common.

1. Brown opaque agate, with black veins, and dendritical figures, which is the Egyptian pebble.

2. Of a chalcedony colour, *Achatés calcedonifans*.

3. Semi-transparent, with lines of a blackish-brown colour, and dendritical figures, which is the mocha-stone.

This is much esteemed, and makes a valuable part of some collections, where it has a place chiefly for the sake of its figures, resembling vegetables, animals, &c. which however are often improved by art.

4. Semi-transparent with red dots, *Gemma divi Stephani*. When the points are very minute, so as to give the stone a red appearance, it is by some called *Sardea*.

5. Semi-transparent, with clouds of an orange colour.

6. Deep-red, or violet, and semi-transparent.

7. Of many colours, and variegated.

8. Black.

There are in Europe great quantities of most varieties of agates, particularly at Oberstein in the Palatinate, where they are cut and polished: but they are likewise found in every part of the world. According to Cronstedt, there is not as yet more than one species of agate found in Sweden, namely, at Gasebeck in the province of Skone, which is of a white and deep red colour.

XXII. The LABRADOR STONE. See the article.

**PRECIPITATE, AND PRECIPITATION.** When a body dissolved in a fluid is either in whole or in part made to separate and fall down in the concrete state, this falling down is called precipitation, and the matter thus separated is called a precipitate. The form of precipitates is usually pulverulent. We see from this explanation, that the terms precipitate and precipitation relate merely to the manner in which any product is obtained, and not at all to its component parts or properties. But as the effects denoted by these expressions continually occur in chemical operations, the words are much and usefully applied.

The most usual effect of precipitation is seen when a compound substance being suspended in a solvent, another substance is added which unites with one of the principles of the compound, and separates the other: and this being insoluble in the fluid, falls down. See **ATTRACTION**. As precipitations require the presence of a fluid, and as most substances may be rendered fluid by fire, it naturally follows, that two kinds might be distinguished, namely, in the dry and in the humid ways. Of precipitations in the dry way some instances may be seen in the Schemes of Electric Attraction of Bergman, p. 187, and under the article **BLOW-PIPE**. But the terms are seldom applied to dry operations; and all the products properly called precipitates are produced in humid processes.

Since the insolubility of the matter which falls down is a condition without which precipitation does not ensue, and is the only condition required to effect it, we might call the separation of salts and other bodies from their solvents by evaporation, by this name. But this is not usual, as the word implies a speedy separation. Chemists are accordingly habituated so to apply it. When a precipitation takes place slowly, they frequently use the word **deposition**.

position. Thus the matter which falls quickly is said to be precipitated; but they say a deposition takes place when the change is not effected but during many hours or days.

The cases of simple and compound precipitations are very perspicuously treated of by Bergman, in his Essay on Metallic Precipitates, from the latter part of which work I shall extract the substance, only altering so much of the language as renders the explanations more peculiarly adapted to the theory of phlogiston than to the pneumatic theory, and rendering it suitable to either by using general terms expressing the simple matter of fact.

There are different methods by which dissolved metals may be separated from their solvents; and the appearance and nature of those precipitates are occasionally varied in a very singular manner. Some of the most remarkable are thus enumerated by Bergman:

All metals may be precipitated by alkaline salts, which by their superior power of attraction separate them from their solvents; but the differences of these alkalis, with respect to their nature and preparation, produce different characters in the precipitates.

With the caustic fixed alkali the calces fall almost entirely pure, but loaded with water, and the matter of heat, which according to Bergman is expelled from the alkalis by the acid. The weight is found to be increased by the water, and perhaps by the matter of heat; but yet less than by the aerial acid, or fixed air, when present.

With the aerated or mild fixed alkali, by means of a double decomposition, the aerial acid unites to most calces. The vegetable alkali, completely aerated, precipitates a white calx from salited mercury; but the mineral alkali does not possess that property, because it cannot hold a sufficient quantity of aerial acid or fixed air for that purpose.

The volatile alkali, which naturally contains inflammable air (See ALKALI VOLATILE), sometimes partially reduces the precipitates: it throws down a black or white precipitate of mercury; nay, makes the orange-coloured calx white. Gold receives from this precipitant its fulminating quality. See GOLD.

The alkali, which is commonly called phlogisticated, generally precipitates metals with an increase of weight, as Macquer first proved.

The acids frequently occasion precipitates, from various causes.

By stronger elective attraction, silver, mercury, and lead are taken from the nitrous acid, by the addition of the marine or vitriolic. These acids form with the metals new compounds, which are difficult of solution in water; they are therefore precipitated in greater or lesser quantity, according to circumstances.

The nitrous acid decomposes the marine solutions of tin and antimony by calcining them beyond that point in which they are soluble by acids.

Alkalis saturated by acids, which are called neutral salts, sometimes disturb metallic solutions; either

By means of a double elective attraction: all those which contain vitriolic or marine acid decompose solutions of silver, mercury, or lead, in nitrous acid, and precipitate the metals; or

By forming a triple combination: thus the vegetable, as well as volatile alkali, though saturated with vitriolic, nitrous, or marine acid, precipitates platina from aqua regia. If the mineral alkali forms the base, the neutral salt has no power of this sort.

Some metallic salts can decompose others, and precipitate their bases. This may



may happen when the acid is different in the two salts, or, what is more singular, even though it be the same.

Solution of gold gives us an example of each of these two cases. This, as is well known, is precipitated by martial vitriol, the reason of which was first explained by Bergman. Upon examining the precipitate carefully it will be easily understood: for this, when washed and dried, not only shews many resplendent gold-coloured particles, but also unites with mercury by trituration, dissolves in aqua regia, but not in marine acid alone, together with other circumstances which evince a complete reduction of the gold. Crystallised martial vitriol contains iron not much calcined, so that the calx of the gold may very easily be reduced on the same principles, as if metallic iron were present. That this is the true foundation of the process, appears also from this, that the weight of the dissolved gold is precisely recovered: it is also proved from this circumstance, that pale vitriol containing iron more perfectly calcined, will not precipitate gold. It may reasonably be enquired why the surrounding aqua regia leaves such a precipitate untouched. The reason is, that the menstruum is diluted and weakened by the quantity of water; for upon boiling it gently, so as to expel the water, the menstruum recovers its solvent power, and takes up the precipitate. Bergman in the next place enquires into the origin of the purple precipitate.

That a solution of gold in aqua regia should be precipitated by a solution of tin in the same menstruum, is of more difficult explanation:—in this case it is the same menstruum that holds the two metals dissolved; what then is the cause of the change? At first Bergman imagined that the tin had attracted a superabundance of the acid, and taken it from the gold, which being therefore destitute of the proper quantity must necessarily fall to the bottom: but upon employing a solution containing superabundant aqua regia the same precipitate was occasioned. The cause was not therefore to be sought in the menstruum: he therefore examined the precipitate itself. Its external appearance shews nothing like the metallic splendor, but altogether resembles a calx: it is easily found by its weight, that it cannot consist entirely of gold; and in fact chemical examination discovers a considerable quantity of tin. It cannot be dissolved by the marine acid alone, but, upon the addition of a little nitrous acid, is easily taken up: triturated with mercury, it scarcely unites with it. These properties seem to indicate that the gold is so far reduced, as to resist the marine acid, unless aided by the nitrous; but its earthy appearance, and its habits with respect to mercury, evince that it is not in its complete metallic form. Bergman therefore offers the following conjectural explanation. The solution of tin necessary for this operation must contain the metal as slightly calcined as possible, consistent with solubility. This is dropped into a solution of gold very much diluted, by which means the tin is more readily disposed to become calcined in a greater degree by the action of the calx of gold, which at the same time approaches nearer the metallic state. Neither metal can then be retained by the acid, for the one is too much calcined, and the other too far reduced: they must both therefore of consequence fall to the bottom, mixed intimately together. It is probable that, in this case, it is the calx of tin which prevents the union with mercury.

Besides, the metals precipitate one another after a certain order. This order is found to be the same in all acid menstrua, as we have frequently had occasion to mention.

But many irregular circumstances occur in this matter, depending no doubt upon accidental circumstances. The order is indeed constant, and never inverted;

verted; zinc prevails over iron; iron over lead; lead over tin; tin over copper; copper over silver; silver over mercury, &c.: yet it sometimes happens that a metal, which, according to the general rule, precipitates another, in its metallic state, from one solvent, precipitates it from another in the form of a calx; and from a third not at all. Some examples will illustrate this:—zinc precipitates iron from marine acid in its metallic state, but from the nitrous only in the form of a calx. Perhaps the calcination which ensues in the zinc may not be sufficient to reduce the iron, which in the latter case has been much more calcined; or perhaps, though less probably, the iron, though separated in the metallic form, may have been afterwards calcined by the nitrous acid. Tin precipitated from marine acid by lead appears in the metallic form; but is not thrown down from nitrous acid; and from vinegar is precipitated in form of a calx, even by iron and zinc: lead lets fall nothing from vinegar upon the addition of iron. These and other anomalies are expressly examined in Bergman's Treatise on Electric Attractions, but in this place he only remarks that a small excess of acid is necessary; and that without it no precipitation begins\*: but a great superabundance prevents that operation, by again dissolving the precipitate; besides, the weights of the precipitates and the dissolved precipitants do not correspond.

The colours of the metallic precipitates are of considerable utility to be known and attended to. Bergman employed the mineral alkali, because the degree of saturation of it with aerial acid is more constant. When he had occasion for a caustic alkali, he prepared it by a small quantity of burned lime, in a close bottle; the goodness of it was proved by its occasioning no precipitation in lime water. For the preparation of Prussian alkali, see that article.

Gold dissolved in aqua regia is precipitated by caustic mineral alkali, almost black; by the aerated yellow; as also by the Prussian, unless some iron be present, which frequently happens. As the whole of the gold is scarcely ever precipitated, Bergman does not pretend to ascertain the weights.

Neither the caustic nor aerated mineral alkali precipitates one half of platina, dissolved in aqua regia; the precipitate is of an orange colour, which on drying changes to a brown. An over proportion of alkali re-dissolves the precipitate with a more obscure tinge; indeed the precipitation is so imperfect that alkali saturated with acid seems to dissolve it. The Prussian alkali does not precipitate the depurated solution, nor even make it turbid; but heightens the colour in the same manner as the excess of alkali does.

Silver dissolved in nitrous acid is precipitated white by aerated mineral alkali; by the caustic, brown; and by the Prussian alkali, of an obscure yellow; by the vitriolic as well as the marine acid, white; but the former precipitate consists of more distinct particles, which grow black more slightly in the light of the sun.

Salited mercury is precipitated red, or rather ferruginous, by aerated alkali; by the caustic, more yellowish, or orange. Nitrated mercury, prepared without heat, yields a ferruginous precipitate with mineral alkali; a black with caustic: when prepared with heat, it yields to caustic alkali an orange, or reddish yellow precipitate: by Prussian alkali it is precipitated from all acids white; which, when dried, becomes of a brownish yellow. Salited mercury is very sparingly precipitated by this alkali. The precipitate occasioned by Prussian alkali is again dissolved, if too much alkali be used.

\* This was first observed by the celebrated Gahn.



It has been shewn already, that a white precipitate may be obtained by aerated vegetable alkali, and the cause of this has been explained.

Corrosive sublimate must be very cautiously precipitated by caustic, as well as aerated fixed alkali; for the part separated may again be dissolved by a large quantity of water. If too much alkali be used, a new compound arises of a peculiar nature.

Nitrated lead is thrown down white by aerated, caustic, or Prussian alkali. If too much alkali be used, the last precipitate is dissolved with a brownish yellow colour. Vitriolated and salited lead is precipitated white.

Nitrated copper, which in solution is blue, is precipitated of a bright green by aerated fixed alkali; by the caustic, of a grayish brown, which grows reddish by age. By Prussian alkali, copper is precipitated of a greenish colour, which afterwards grows of a brownish red, and upon exsiccation almost black. The aerial acid readily takes up a small portion of copper during the precipitation, which is again deposited by the heat of boiling.

Iron is precipitated green by the aerated fixed alkali, from vitriolic and marine acid; this precipitate becomes of a brownish yellow, especially on drying; with the caustic alkali it approaches more to black: in the precipitation some part is held in solution by the aerial acid, if the aerated alkali be used: the Prussian alkali yields a dark blue precipitate.

Tin is precipitated white by every alkaline salt, even by the Prussian alkali; but at length some blue particles, which are mixed, appear, so that the whole, when collected and dried, is of a light blue colour. That these blue particles depend upon iron is easily seen upon calcination, for they become ferruginous and obey the magnet. Bergman always found an admixture of iron in tin.

Bismuth is precipitated white by water and alkalis, particularly the former; Prussian alkali throws down a yellow powder, which being mixed with blue particles, occasioned by iron, at length appears green. This yellow sediment easily dissolves in nitrous acid.

Nickel is precipitated of a whitish green by fixed alkalis; by the Prussian alkali, of a yellow; and by exsiccation it is condensed into a dark brown mass.

Arsenic dissolved in acids, which prevent too great calcination, may, to a certain degree, be precipitated white by the fixed alkali, even when phlogisticated, but the sediment is found soluble in water; yet nitrous acid, either alone or joined with the marine, generally calcines the arsenical acid, to such a degree that it becomes unfit for separation. Arsenic, dissolved in marine acid, with the addition of a little nitrous acid deposited a white sediment; upon the addition of a large quantity of Prussian alkali, the sediment was mixed with Prussian blue; this was dissolved in water, and freed by frequent filtration from the blue particles, and at length, on evaporating to dryness, yielded a semi-pellucid mass.

Cobalt dissolved in acids is thrown down by fixed alkali, whether aerated or caustic, of a reddish blue, which colour on drying grows darker, especially when the former alkali has been used. Prussian alkali throws down a powder of almost the same colour, which upon drying becomes of a reddish-brown.

Zinc is precipitated white by aerated and caustic fixed alkali, as also by the Prussian alkali; but this last, on drying, becomes of a citron colour. A small portion of aerial acid may easily escape during the precipitation.

Antimony is precipitated white by alkalis. When the Prussian alkali is used, there are almost always some blue particles precipitated, though the regulus had been

been prepared without any iron. The operation must be cautiously conducted, otherwise some part may be taken up by the alkaline salt.

Manganese, which is procured by reduction from common *magnesia nigra*, generally renders solvents brown, and with aerated alkali yields a yellowish-brown sediment; with the caustic, one still darker; with the Prussian a powder is separated, at first blue, then a white, the mixture of which renders the mass a darkish, or rather a black-green. In order that the calx of the manganese may be obtained pure and white, the precipitate afforded by caustic alkali must be dissolved in pure vinegar; for there still remains a quantity of undissolved iron, which would be taken up by the aerial acid if present. This acetous solution contains scarcely any iron. That metal may also at first be separated by a small quantity of volatile alkali.

The common solution of the regulus is not perfectly precipitated by aerated alkali: and if the remaining fluid be left to evaporate spontaneously to dryness, grains of a metallic splendor are deposited on the glass, which are not unlike copper. These are readily, though but partially, dissolved in nitrous acid; but upon the addition of zinc, nothing falls but the manganese, though at first it is a little reddish. With Prussian alkali, a yellow precipitate, resembling pure manganese, falls, provided the solution has first deposited the iron by standing; but the recent solution yields a precipitate nearly the same as is obtained from the common regulus. The yellow sediment is soluble in water.

A considerable difficulty always attends the description of colours, because the several varieties, which are almost innumerable, have no particular names. Colours are indeed subject to changes, but the smallest never occurs without some determinate cause; they should therefore be carefully observed, for we may always learn something, provided we consider every thing with due attention.

A due consideration of the metallic precipitates will explain many obscurities in the science of chemistry.

The first inquiry of Bergman relates to their weight. He examined only those precipitates which are occasioned by aerated mineral alkali, caustic alkali, and Prussian alkali. The results of many experiments were rejected, as too vague and indeterminate; but he expresses his hope that the rest were better founded. However, upon reflecting how difficult it is to depurate and wash completely the metallic sediment, so that neither the alkali, the aerial acid, the water, nor any other extraneous matter shall adhere, he considers them only as collections of the first terms of infinite series, which converge very quickly. In order to obtain the nearest possible approximation, he frequently repeated the experiments in the most accurate manner. In the following table 100 parts of the metallic regulus are always supposed to be dissolved.

				Dry Precip.
100 parts of	Gold	precipitated by	aerated mineral alkali	yielded 106
			caustic	— 110
			Prussian	—
			marial vitriol	— 100
	Platina,		aerated mineral alkali	— 34
			caustic	— 36
			Prussian	—
	Silver,		aerated mineral alkali	— 129
			caustic	— 112
4 X				100 parts



100 parts of	Silver,	precipitated by		Dry Precip.
			Prussian alkali — —	145
			salited — —	133
			vitriolated — —	134
	Mercury,		aerated mineral alkali — —	110
			caustic — —	104
			Prussian — —	
			vitriolated — —	119
	Lead,		aerated mineral alkali — —	132
			caustic — —	116
			Prussian — —	
			vitriolated — —	143
	Copper,		aerated mineral alkali — —	194
			caustic — —	158
			Prussian mineral alkali — —	530
	Iron,		aerated mineral alkali — —	225
			caustic — —	170
			Prussian — —	590
	Tin,		aerated mineral alkali — —	131
			caustic — —	130
			Prussian — —	250
	Bismuth,		aerated mineral alkali — —	130
			caustic — —	125
			Prussian — —	180
			pure water — —	113
	Nickel,		aerated mineral alkali — —	135
			caustic — —	128
			Prussian — —	250
	Arfenic,		aerated mineral alkali — —	
			caustic — —	
			Prussian — —	180
	Cobalt,		aerated mineral alkali — —	160
			caustic — —	140
			Prussian — —	142
	Zinc,		aerated mineral alkali — —	193
			caustic — —	161
			Prussian — —	495
	Antimony,		aerated mineral alkali — —	140
			caustic — —	138
			Prussian — —	138
	Manganese,		aerated mineral alkali — —	180
			caustic — —	168
			Prussian — —	150

Upon comparing these weights, a question at first occurs concerning the cause of such enormous differences; and it is plain that this cause must be sought for in the precipitates themselves. The fixed alkali, saturated with aerial acid, when added to the solution, is taken up by the more powerful menstruum, and the weaker is of course expelled, and is absorbed by the calx, as it falls in greater or lesser quantity according to circumstances. That this is actually the case is easily

easily demonstrated:—let a bottle, containing a sufficient quantity of nitrous acid, be accurately weighed; let there be put into it by degrees, e. g. 132 parts of lead, precipitated by aerated alkali, and not only an effervescence will be observed, which continues until the very last particle is dissolved; but when the solution is finished a deficiency of weight is discovered, which amounts nearly to 21, and which is indubitably owing to the extrication of aerial acid. But  $132 - 21 = 111$ , a weight which still considerably exceeds that of the metal. Upon distillation nearly 8 of water are discovered; there yet remain therefore 3, which by violent heat are increased by 7; for 132 of the calx, well calcined, yield 110. The whole increment of weight then does not depend upon the water and aerial acid. The same thing is evinced from the consideration of the precipitate of lead by the caustic alkali, as it is evident that in this case there is no aerial acid; besides, no effervescence accompanies the solution. If we suppose the quantity of water equal in both cases, yet, even on this supposition, the whole excess is not accounted for, for  $116 - 8 = 108$ . Bergman thinks it probable therefore, that the matter of heat is attached to the calx, and reasons as follows: This matter of heat is always present in caustic alkali; for when it is dissolved in the simple acids, heat is always generated. And again: 1st. The increment of weight can scarce be conceived, without supposing an increment of matter. 2d. When the caustic alkali is employed, no other matter can be suspected. 3d. The same cause is also present when the weight is increased by dry calcination. 4th. Let the heat occasioned by the mixture of determinate portions of any acid and caustic alkali be marked upon a thermometer: let then an equal quantity of the same menstruum be saturated with a metal; afterwards, upon the addition of an equal quantity of caustic alkali, it will be found either that no heat is generated, or a degree very much less than before. Some of the matter of heat therefore is taken up and fixed\*, which also generally makes the colours of the precipitates more obscure, and in distillation with sal ammoniac communicates to the volatile alkali the quantity that had been taken away. What has been said of lead is also true of the other metals, a few excepted, which seem to take up little or no aerial acid; these are tin, antimony, gold, and platina.

But some precipitates retain also a quantity of the menstruum. Thus, corrosive sublimate, precipitated by aerated alkali, retains a portion of marine acid, which cannot be washed off by water; but by caustic alkali the precipitate may be obtained, either free of the acid altogether, or in a great measure. In this case, as in many others, the aerial acid seems to generate a triple salt, which is scarcely soluble. The presence of the marine acid is easily discovered by nitrated silver, if the precipitate be previously dissolved in pure nitrous acid. Hence we observe another difference in mercury precipitated from marine acid, according as aerated or caustic alkali has been employed: the latter precipitate, well washed and put into volatile alkali, is scarcely changed in colour; but the former instantly grows white, generating a species of sal alembroth, but containing so little marine acid as not to be easily soluble in water.

The calces, which retain any of their former menstruum, generally give over on distillation a small portion of sublimate. The mercurial calx, just mentioned, exposed to a sufficient degree of heat, is partly reduced to crude mercury, partly

\* The increase of weight acquired by metals from the absorption of vital air in calcination was less known and attended to at the time the great Bergman composed his Treatise on Metallic Precipitates than since; otherwise this fact would have afforded an easier solution of the present difficulty, than the violent supposition of material and ponderable heat.



to mercurius dulcis, by means of its remaining marine acid. This mercurius dulcis did not exist in the precipitate; for in that case it would be easily discovered by acids, in which it is not soluble, and would grow black with caustic alkali; neither of which things takes place; it is therefore generated during the distillation.

The Prussian alkali has the same property with regard to salts and soluble earths, as acids, in the state called phlogisticated, possess. Its compounds with metals are of a saline nature, though mostly insoluble in water.

The excellent treatise of Bergman concludes with pointing out some of the advantages resulting from the examination of metallic precipitates.

It is evident, that by a more intimate acquaintance with these precipitates, the chemical theory of the operation will be better understood.

Hence we may discover their more useful and remarkable properties. Every one knows that aurum fulminans, the mineral purple, and other encaustic pigments, by which the colours of gems may be imitated, have been derived from this source.

A foundation is by this means established for the art of assaying by the humid way, from the bare knowledge of the weights. It may be objected, that the doctrine of the weights is very fallacious; that they vary in the different precipitates; that by imperfect precipitation something remains in the liquor; and that extraneous matters sometimes are mixed with them. All this is true; yet if the mode of operation be always the same, the results of the experiments must be constant. Let us suppose that a quantity of metal, precipitated in a certain manner, makes a weight; if that same manner be exactly employed, we may fairly conclude that a quantity of precipitate, occurring in any case, is correspondent to a quantity of perfect metal; although in the fundamental experiment either the precipitation is incomplete, or some extraneous matter is present. If all the circumstances which occasion increase or deficiency be carefully attended to, the conclusion will remain unimpeached: let the method therefore be accurately determined, and there will be no danger of fallacy.

Hence the nature of metals is illustrated. Platina, nickel, cobalt, and manganese, are suspected by some persons to derive their origin from a mixture of other metals. But if iron necessarily enters into the composition of platina, when this is dissolved in aqua regia it should produce a blue upon the addition of Prussian alkali; and this is the case in fact when common platina is employed, but not when it is rightly depurated. See PLATINA.

If iron, adhering very obstinately to nickel, formed a great part of it, the precipitates obtained from it by alkalis could not differ from martial precipitates so much as they do, in colour, weight, and other properties.

The same is true of cobalt and manganese. The regulus obtained from black manganese contains about 0,08 of iron: let us see how this affects the mixture.

One hundred parts dissolved in an acid menstruum yield to phlogisticated alkali a powder, consisting partly of blue, partly of brownish-yellow particles, which is equal in weight to 150lb.; but 8lb. of iron yield 48 of Prussian blue, nearly  $\frac{1}{3}$  of the whole mass: hence it follows, that 100 parts of pure manganese yield to phlogisticated alkali scarcely 111, i. e. nearly six times less than an equal weight of iron.

Lastly, Bergman remarks, it may by this means perhaps be possible to determine the unequal quantities of phlogiston in different metals; for a given weight of precipitating metal does not yield an equal quantity of precipitate: thus for example,

example, copper is able to precipitate from nitrous acid four times its own weight of silver.

This object is more completely developed in his Treatise on the Quantities of Phlogiston in Metals, of which we have no English translation \*. In the following account I shall not so far depart from the author as to substitute the words basis of vital air instead of phlogiston, which is all the conversion this valuable mass of facts requires, to adapt it to the antiphlogistian theory. In its present form, indeed, the agency of vital air in the calcination is overlooked. But if the great author had lived longer, he would doubtless have added a modification of this doctrine to the other improvements which the sciences have unhappily lost by his death.

The general facts relating to the quantities of metals precipitated by metals are given by him in the form of equations. It may perhaps be more convenient to readers in general to see them in words at length.

There are six things to be considered when this effect is intended to happen.

1. The metal already in solution. 2. The quantity of solvent which sustains it.
3. The quantity of phlogiston lost (or vital air acquired) by the metal. And
4. The metal presented, or the precipitant. 5. The quantity of solvent required to take up a portion of this metal equal to that held in solution. 6. The phlogiston it contains (or vital air it would acquire by solution). Then,

1. If the weights of solvent (2 and 5) be equal;

And also the quantities of phlogiston (3 and 6) there will be no difficulty in the precipitation. For the solvent is capable of dissolving as much of the one metal as of the other, and the precipitate can take as much phlogiston from the precipitant as its reduction demands.

Again: if the quantity of phlogiston in the precipitant exceed that required for the reduction of the precipitate, there will be no obstacle to the effect.

But if the phlogiston of the precipitant be less than the precipitate requires, a part only of this last will fall down; unless the precipitation be aided by some cause of a different nature from those here attended to.

2. If the weight of solvent required to sustain the precipitant be less than would sustain an equal portion of the metal intended to be thrown down, the effect with regard to phlogiston will be the same as in No. 1. but the obstacles will be less.

3. If the weight of solvent, required as in the last case, be greater than would sustain the metal intended to be thrown down, the whole of the precipitant will not be dissolved, and the precipitate will not be entirely separated, unless the phlogiston of the precipitant so much exceeds that required by the precipitate, as that the portion of the precipitant dissolved may supply the whole requisite quantity of that principle.

This excellent chemist then proceeded to apply these general principles to the test of experiment. Among the several processes, he chose to institute two sets. In the first, silver was taken as the term of comparison, because it is precipitated from nitrous acid by all the metals but gold and platina: and in the second set he made use of zinc, which is a precipitant to them all.

One hundred docimastic pounds of silver were dissolved in nitrous acid with as little excess of acid as possible. For all metallic salts redden the tincture of turnsole, and cannot be deprived of this small excess without decomposing the

\* There is a French Translation in the Journal de Physique, xxii. 109.



salts. To the solution was added twice the quantity of distilled water, and then mercury was added at several times. Various crystallizations of the arbor Dianæ were afforded, as the proportions of the mercury varied. In fact, where the mercury was most abundant in proportion to the silver to be precipitated, the vegetations were more slowly produced; but were more beautiful, more brilliant, stronger, and sometimes crystallized in prisms. The mercury when thrown into the solution of silver hardens; its surface becomes irregular, and at last it puts forth branches which increase by slow degrees. These branches, collected, washed, and dried, weighed 455 pounds. The whole of the mercury added was 490 lbs. Consequently there were  $455 - 100 = 355$  pounds of mercury amalgamated with the silver, and  $490 - 355 = 135$  pounds of mercury dissolved in the acid.

Two hundred and thirty-four lbs. of lead were required to precipitate one hundred of silver. The plate of lead soon becomes black on immersion, and is quickly covered with small crystalline needles of silver. The last portions are thrown down very slowly, if recourse be not had to heat. The precipitate being collected always weighs eight or ten pounds more than the quintal, evidently from some of the lead which falls in the calciform state.

A plate of very clean copper, weighing 375 pounds, was very quickly covered with a crystalline crust of silver, after it had been plunged into the solution. When all the silver had fallen down, the plate of copper well washed was found to have lost thirty-two pounds. The precipitate of silver proved to be exactly the quintal.

With the intention of ascertaining the different force of solvents, Bergman added copper to a vitriolic solution of silver. Thirty pounds were sufficient to precipitate the quintal of silver. Whence he remarks, that the nitrous acid possesses a greater avidity for phlogiston than the vitriolic. The pneumatic chemist would say, that the one acid is more easily decomposed, and made to afford vital air to the calx, than the other.

Iron exhibited a very peculiar character. In general no precipitation took place by adding iron to the nitrous solution, and the facts are highly interesting and remarkable. But as Bergman has not offered any explanation, and other experiments appear to be wanting, I shall not here enter into any detail\*.

Silver dissolved in the vitriolic acid is precipitated very speedily and well by iron. The iron plate lost thirty-nine pounds in precipitating one hundred pounds of silver.

Those metals which the vitriolic acid dissolves readily are more easily precipitated than from a similar nitrous solution. This fact ought to be kept in mind in the humid method of analysis.

Tin in leaves precipitates silver very speedily from the nitrous acid. It has even the crystalline form; but the fluid speedily becomes black, and frequently continues so for four-and-twenty hours. Eighty-eight pounds of tin precipitated the quintal of silver at a moderate heat; but the precipitate well washed amounted to two hundred and fifteen pounds. This increase of weight arose from the calx of tin which fell down with the precipitate of silver. It was contaminated by a blackish matter, probably an impurity.

Bismuth at the first instant precipitates silver very well; but towards the end it is very difficult to ascertain the necessary quantity. A solution of bismuth perfectly saturated cannot support either heat or dilution with water, without depositing a white powder which mixes with the precipitate, and cannot be se-

\* Keir in the Phil. Trans. for 1780 has thrown some light on this object, and promises to consider it farther.

parated but with extreme difficulty. The precipitate of silver is so spongy that it absorbs the whole of the fluid; so that towards the end there is not enough to dissolve the bismuth, and no distinct observation of the effect can be made. When this difficulty began to present itself, Bergman endeavoured to express the fluid from the sediment between two plates of glass. Out of this fluid he precipitated the bismuth by the addition of water; and after decantation, the silver was separated by marine acid. Hence, from the weight of silver in the saline state, he acquired a knowledge of the quantity which had been precipitated by the known weight of bismuth. By this expedient he found, that the thermometer being at  $15^{\circ}$  (of Celsius, which answers to 59 of Fahrenheit) one hundred and seventy-four pounds were required. When the precipitate was washed, the water was rendered turbid, and seemed to carry off some portions of bismuth. The whole sediment weighed one hundred and eighty pounds. The first parcels of bismuth, instead of becoming black upon immersion, became white, and were covered with small brilliant crystallizations of silver. Towards the middle it is dissolved without losing its lamellated structure, and assumes a whitish earthy aspect, seldom of a metallic appearance; but towards the end, the pieces which are continued to be added become immediately black.

Nickel, as soon as it is put into the solution of silver, turns the fluid green, and some precipitation seems to take place; for metallic and brilliant spots, though few and slowly produced, are seen upon the surface. The operation was not hastened by excess of acid, and a digesting heat. It is absolutely necessary to reduce the semi-metal to a fine powder; a manipulation which is unnecessary for all the other metals, regulus of arsenic excepted. It is very difficult to make an experiment with accuracy, when a precipitate is to be thrown down, by the gradual addition of a pulverulent matter. Sixty-four pounds of nickel are required to throw down one quintal of silver. The precipitate is full of small crystals, and contaminated by a brown powder. It weighed in the whole one hundred and sixteen pounds.

Of all the metals, arsenic precipitates silver with the greatest difficulty. It must be pulverized; for, if it be in fragments, its surface becomes white, and the interior part is not attacked, and it would be to no purpose to employ either an excess of acid or evaporation to dry this. Ninety-two pounds precipitate the quintal of silver. The precipitate washed and dried amounted to one hundred and forty pounds; the increase being owing to the calx of arsenic.

The quintal of silver is precipitated by thirty-nine pounds of cobalt, in the crystalline form, without the assistance either of heat or pulverising. The solution immediately becomes red.

Zinc is blackened as soon as it is immersed in the solution of silver. It becomes covered with an ash-coloured moss, which in a few moments acquires the brilliancy of silver. Fifty-five pounds are sufficient for the precipitation. The introduction of this precipitant produces heat.

The precipitation is equally well effected by the regulus of antimony. The precipitate has even a peculiar appearance. The revived metal resembles twisted fragments of silver leaf. The solution will bear diluting, but not heat, which prevents the last portions of silver from easily separating. About eighty-three pounds of the precipitant are required, and the precipitate weighed two hundred pounds, viz. double the weight of the silver employed. This increase arose from the calx of antimony, which was almost totally precipitated; for the fluid scarcely contained a few pounds.

Manganese



Manganese becomes immediately covered with a pellicle of silver. A powder was produced during this operation, partly black and partly greenish, which weighed eleven pounds. Forty-four pounds of the precipitant were required, and the precipitate was more solid than with the other metals; it was yellowish.

From the preceding experiments, the several metals are comparable with each other, in the character of precipitants of a common substance, namely, silver. In the following experiments, they are comparable in another way, viz. as precipitates, by the common substance zinc.

A quintal of pure gold dissolved in aqua regia, with the least possible excess of acid, required two hundred and seventeen pounds of zinc for its precipitation.

A like quantity of gold was precipitated by three hundred and one pounds of English tin. Sixty-six pounds of gold were completely revived; and one hundred and sixty pounds of a black purple were obtained. The rest of the liquid had still a purple tinge; but it was not decomposed at a moderate heat, by the addition of a new quantity of tin. One hundred and fifty-eight pounds of zinc precipitated a powder inclining to purple, which when washed and dried weighed two hundred and twelve pounds.

A quintal of crude platina was dissolved in aqua regia until the menstruum would take up no more at a boiling heat. It required, however, four hundred and sixteen pounds of zinc to bring the solution to complete saturation. The fluid acquires a blood colour, and is filled with black particles which separate with a lively effervescence. After this intestine commotion has subsided, a black powder falls, which when washed and dried weighs seventy-seven pounds. The remaining liquor is yellowish, and affords small crystalline grains by evaporation, especially if a minute portion of vegetable alkali be added. The black powder urged by the flame, before the blow-pipe on charcoal, first emits white fumes, and then resumes the metallic brilliancy, not perfectly white, but grayish. It is not magnetical, either before or after this application of heat.

The phenomena of zinc and silver have already been described.

One hundred pounds of mercury require forty-four pounds of zinc to precipitate them from the nitrous acid.

The quintal of lead dissolved in the same acid, is precipitated by twenty-six pounds of zinc. That which falls at a moderate heat possesses the metallic aspect at first, and is even crystallized; but soon afterwards it becomes converted into a white powder. By the heat of ebullition, a calx only is obtained, which when washed and dried weighs one hundred and twenty-four pounds.

One hundred and sixty-four pounds of zinc precipitate one hundred of copper dissolved in the nitrous acid. The solution, which is at first blue, becomes afterwards green. Besides the copper in the metallic state, a powder is precipitated, partly white, and partly greenish. The whole precipitate weighs two hundred and eleven pounds.

Thirty-eight pounds of zinc precipitate twenty-six of copper, from a quintal of blue vitriol.

Iron dissolved in the nitrous acid affords, upon the addition of zinc, nothing but a mere calx, the same as would have separated spontaneously, so that it is impossible to ascertain any decided proportion.

One quintal of green vitriol put into a closed matrafs, and without any heat, to prevent the calcination of the precipitate, let fall nothing but a small quantity of ochreous sediment, and the semi-metal was not diminished at the end of eight days.

Sixty.

Sixty-eight pounds of zinc are required to precipitate one quintal of tin dissolved in aqua regia. The precipitate has not the metallic aspect. It is a white calx, and weighs one hundred and forty-nine pounds. Forty-nine pounds of zinc precipitate one hundred of bismuth dissolved in the nitrous acid. At a moderate heat it has the metallic form; but at a superior temperature, a calx only is obtained, which weighs one hundred and thirty-three pounds.

A quintal of regulus of nickel dissolved in nitrous acid let fall eighty pounds of a black matter, which was almost entirely arsenic in the reguline state. Fifty-four pounds of zinc are required for this purpose. By a longer digestion with this semi-metal, nothing more is separated but a powder of a greenish white, which is a mixture of the calces of zinc and nickel. The rest of the solution remains as perfectly green as before. It appears therefore, that the arsenic which still remains in the first regulus of nickel may be separated better in this way than by repeated calcinations.

Zinc immersed in a solution of a quintal of regulus of arsenic in aqua regia, precipitated at first nothing but some blackish particles, which became white during digestion, and increased in quantity by the addition of more white powder. The weight of the precipitate was one hundred and twenty-three pounds, and the loss of the precipitant one hundred and twenty-six.

Cobalt lets fall by the addition of zinc assisted by a digesting heat, a powder which weighs thirty-one pounds. The colour of the solution remains unchanged, and the weight of the zinc is very little altered, though the evaporation be carried repeatedly to dryness.

The solution of a quintal of regulus of antimony in aqua regia is precipitated by seventy pounds of zinc. The antimony is recovered in the form of a white powder, and the solution cannot be had very clear, but by means of excess of acid. The precipitate is more or less charged with calx of zinc, according to the intenseness of the heat.

Manganese lets fall the foreign substances which may be united with it more or less readily than iron, nickel, and cobalt. The piece of zinc becomes red, if copper be present, though in small proportion, and this foreign metal may be better precipitated in this than in any other way. A green and white powder is deposited, which phenomenon has already been noticed in copper alone.

The important consequences deduced by Bergman from the preceding experiments are as follow :

The metals adhere to the different acids in different degrees of dephlogistication. For example, one hundred pounds of silver dissolved in the nitrous acid require thirty-two of copper for their reduction, whereas in the vitriolic we have seen, that no more than thirty of copper are necessary. Again, one hundred pounds of copper in the vitriolic acid require no more than one hundred and forty-six of zinc, but in the nitrous acid, one hundred and sixty-four. Again, twenty-three pounds of copper precipitate the quintal of mercury from nitrous acid, but in the marine acid, sixteen pounds are sufficient. Whence it may be concluded, that the nitrous acid dephlogisticates, or calcines the metals to a high degree; the vitriolic acid somewhat less, and the marine still less.

Since the solutions were made with the least possible excess of acid, it must follow, from the weights of the precipitant and the precipitate, that the respective quantities of phlogiston parted with by equal weights of the metals during solution, will be inversely proportioned to those weights. Whence if the quan-



tity of phlogiston thus determined be expressed by the number 100, for the centenary of silver; the quantity contained in mercury will be 74; in lead 43; in copper 312; in iron 256; in tin 114; in bismuth 57; in nickel 156; in arsenic 109; in cobalt 270; in zinc 182; in antimony 120; and in manganese 227.

These deductions are made from the precipitates by silver. In order to compare them with the experiments wherein zinc was the common measure, the quantity of phlogiston in that metallic substance must be assumed to be 182, conformably to the preceding deductions. From this calculation the quantities will be, for the quintal of gold 394; of platina 756; of mercury 80; of lead 47; of copper 292; of bismuth 64; and of antimony 127. The inconsiderable differences between these numerical quantities require to be examined by new experiments. Among these facts, Bergman considers the experiments with silver as most worthy of confidence, because a single grain of sea salt immediately shews whether the whole of the silver has been precipitated, and the dissolved silver does not lose its character and other properties.

By the application of the principles established at the beginning of this extract, relative to the silver considered as a precipitate, it is observable that the weight of solvent required to dissolve one hundred parts of the precipitant, does in no instance prove accurately equal to that which has suspended the same quantity of metal which affords the precipitate. The quantity of solvent for equal portions of lead and of mercury is greater than for silver; but for copper, iron, tin, (bismuth) nickel, arsenic, cobalt, zinc, and manganese, it is less. Zinc considered as a precipitant likewise affords no examples wherein these quantities are equal. For platina, iron, and antimony, the quantity of solvent for the precipitant is greater than for an equal portion of the precipitate; but in all the other instances it is less.

Bergman suspects, not without motives, that the quantity of solvent required for the precipitate being greater, and the quantity of phlogiston required to be imparted by the precipitant, being either equal to or greater than that required by the precipitate, will be the consequence of a more abundant solution of the precipitant than is necessary to reduce the metal which is precipitated. If this suspicion be real in all similar cases, it will affect the ground of these calculations. A scrupulous attention to the phenomena may probably explain this difficulty. Every solution of metal is accompanied with the development of an uniform fluid, which escapes with effervescence; but its precipitation when the solution is saturated does not exhibit this phenomenon; or at least the bubbles of air which appear are very small and seldom observed. Iron, which is easily attacked by all solvents, remains unaltered for many weeks in the nitrous solutions of lead and silver. Bergman has few doubts with regard to the precipitations of silver, because they were well made, and all the phlogiston is preserved; but those in which zinc is the agent are not entitled to the same confidence. For in some, the point of saturation is difficultly observed; in others, effervescence appears; and lastly, in others the precipitate and precipitant unite. The next paragraph but one shews how it happens, when the menstruum which has dissolved the first metal is not sufficient to dissolve the requisite quantity of the second, or when the precipitating phlogiston is insufficient, that the reduction is not completely made.

Most of the precipitated metals possess the metallic aspect. In this case they are always crystallized. But it sometimes happens that the phlogiston received in the humid way adheres so slightly, that it readily quits them without any remarkable

able heat. Such are lead, bismuth, arsenic, and antimony; and what is more remarkable, it sometimes quits them, before the metal has arrived at the bottom of the vessel. Tin in particular exhibits this remarkable fact.

The comparison of the weights shews in the most positive manner, that it is not seldom that a portion of the precipitant falls down likewise in the state of calx, which sometimes arises from the want of phlogiston, or of solvent. The phlogiston of a quintal of lead, for example, being only 45, there will be 234 pounds of this metal required to reduce a single quintal of silver: but 234 pounds of lead require a much greater quantity of nitrous acid for their solution than 100 pounds of silver; and in order that a sufficient quantity of phlogiston may be afforded, it is necessary that the calcined lead should be precipitated from this defective quantity of menstruum by the metallic lead which is afterwards added.

In other cases the two metallic calces unite, and fall down in the most intimate state of union; such are those of copper and zinc, tin and gold.

Most of the precipitants become first black, then are bristled over with small ash-coloured needles, which speedily assume the metallic aspect. These are the different degrees of revivification.

From the preceding series of experiments, Bergman deduces the affinity of the metals with phlogiston to be in the following order: platina, gold, copper, cobalt, iron, manganese, zinc, nickel, antimony, tin, arsenic, silver, mercury, bismuth, and lead. It may here be remarked, that this is not the order of chemical attraction, but an order relative to the quantities of this supposed principle, which each metal loses as the precipitant of zinc, or takes when precipitated by silver. That the chemical attractions have not yet been shewn to bear any direct relation to the quantities of two principles united to a certain point of saturation, is explained under the article *ATTRACTION*. If mature reflection be had on the different stages of calcination of metals, it will be seen, that though this great work of Bergman has furnished us with many admirable conclusions, much yet remains to be done, both in the way of experiment and the explanation of facts, before this subject will be nearly exhausted.

In the antiphlogistic theory, the transfer of the base of vital air, or the oxygenous principle, from one metal to another, according to their respective attractions, will explain all the preceding effects without the assistance of phlogiston. M. Lavoisier has put the result of Bergman's experiments into another form, to express the quantity of oxygen, or base of vital air, required to dissolve 100 grains of each of the metals. For by his own experiments he finds that mercury in the quantity of 100 grains acquires eight grains by solution and precipitation in the state of calx. Now the quantities of oxygen will be respectively in the same inverse proportion of the weight of the precipitates, as Bergman before deduced the quantities of phlogiston to be. Whence he computed the following table:

<i>Metals.</i>	<i>Oxygenous principle.</i>	
	Gr.	For solution merely.
100 grs. of Platina	— 81,690	
Gold	— 43,612	
Iron	— { 27	
	— { 37	
Copper	— 36,000	15,85
Cobalt	— 29,190	
Manganese	— 21,176	
	4 Y 2	

*Metals,*



*Metals.**Oxygenous principle.*

		Gr.	For solution merely.
100 grs. of Zinc	—	19,637	
Nickel	—	14,721	
Reg. of ant.	—	13,746	22,383
Tin	—	14	23,555
Reg. of arf.	—	{ 11,739	24,743
Silver	—	10,800	
Bismuth	—	9,622	
Mercury	—	8,000	
Lead	—	4,470	14,190

**PRECIPITATE (BLACK AND ROSE-COLOURED).** Lemer, who mentions many precipitates of mercury of different colours, says, that if a solution of mercury in acid of nitre be precipitated by urine, instead of a solution of common salt, a rose-coloured precipitate of mercury will be formed; and that if afterwards some fixed or volatile alkali be added to the liquor from which the rose-coloured precipitate has been formed, another precipitate which is black will be obtained.

The rose-coloured precipitate consists of mercury united with the phosphoric acid, and the black appears to be mercury nearly reduced. This last must be most abundant, where the mercurial solution has been made by heat. See *MERCURY*, p. 486.

**PRECIPITATE (GREEN); AND PRECIPITATE (BLACK); OR VIOLET-COLOURED, OF MERCURY.** Some authors, particularly Lemer, give processes for other preparations of mercury, which have been employed as remedies, and which are improperly called precipitates. Such is green precipitate, which is a mixture of four parts of mercury and one part of copper, dissolved separately in the nitrous acid, and treated as in the process for making red precipitate; afterwards, partly dissolved a second time by being digested with vinegar; and lastly, reduced by evaporation to a dry consistence. Such also is the preparation called by Lemer violet mercury, or black mercurial panacea, or black precipitate, which is an artificial cinnabar overcharged with sulphur, mixed with sal ammoniac, and prepared by a very long and laborious process: but as these preparations have been made only for the use of medicine, and have fallen into disrepute, we shall not say any more of them, excepting that they are singular mixtures, accompanied with many unforeseen appearances, which could not be explained without further examination and particular dissertations.

**PRECIPITATE PER SE.** This preparation of mercury is very improperly called a precipitate; because it is not separated from one substance by means of another substance, as all true precipitates are, but is only mercury reduced to a red powder by calcination.

To make this preparation, three or four ounces of mercury are put into a flat-bottomed glass matrafs, the neck of which is very long, and the opening of a capillary size. This matrafs, the belly of which ought not to be entirely full of mercury, is to be placed in a sand bath, and heated till the bottom of the vessel containing the sand be red-hot. This heat is to be continued during two or three months. The mercury gradually loses its lustre, and part of it is converted into a red powder, which does not mix with the remaining fluid mercury, but floats upon the surface of the mercury; or adheres to the sides of the vessel. The

operation may be shortened by using a greater number of matrasses, all which may be placed in the same bath. When enough of this red powder is obtained, it is to be collected and separated from the remaining fluid mercury. This is called precipitate per se, or by itself, or red precipitated mercury without addition.

This preparation of mercury we have received from the alchemists, who spared no pains to change mercury and to fix it. They received great hopes from the change of colour, the want of fluidity, and the diminution of volatility which the mercury suffers by this operation. Although the mercury is much disguised by these changes, yet it is not greatly altered, because it may be reduced to fluid mercury by heat without addition. It is a combination of mercury with the vital air of the atmosphere.

**PRECIPITATE (RED).** If a solution of mercury in nitrous acid be reduced to dryness by evaporation, and the mercurial nitre thence formed be put into an open matras set in a sand-bath, with a fire gradually increasing, the nitrous acid will disengage itself from the mercury, and evaporate in a red vapour. While the acid evaporates, the saline mercurial mass loses its original whiteness, becomes yellow, then orange, and lastly red.

This red matter, when separated from the matras (which must be broken for that purpose) and pulverised in a glass-mortar, is the red precipitate as it is improperly called; it not being a precipitate, but a mercurial calx from which the greatest part of the acid has been expelled by the fire, without the application of any intermediate substance.

The acid is decomposed. Its azotic part flies off, and the vital air remains in combination with the mercury. This precipitate, therefore, when well made, does not differ from the precipitate per se.

**PRECIPITATE (YELLOW).** As chemists have given many different forms to mercury, to adapt it to medicinal uses and to chemical processes; so they have made various precipitates of it, and have given the name of precipitate to other mercurial preparations, which in fact are not precipitates. These are chiefly denominated from their colours, without adding any epithet to shew that they are mercurial. Thus, white precipitate, yellow precipitate, red precipitate, &c. are preparations of mercury. Yellow precipitate is mercury dissolved by vitriolic acid, from which it is afterwards separated by addition of water alone; it is then in form of a yellow powder. See **TURBITH MINERAL**.

**PRECIPITATE (WHITE).** This is mercury separated from nitrous acid by marine acid, with which it then unites. White precipitate is made by pouring a solution of common salt in distilled water into a solution of mercury in nitrous acid, till no more precipitate falls. When the sediment is collected at bottom, the supernatant liquor is to be decanted, and the precipitate is to be washed several times with distilled water, and then dried.

This precipitate of mercury is one of those called compound. It is a combination of mercury with the acid of common salt; for in this operation, as well as in the precipitation of the corneous metals, the metallic matter is only separated from the nitrous acid by means of the combination it forms with the marine acid. In this precipitation, then, the phenomena are similar to those which happen in the formation of luna cornea and plumbum corneum. 1. White precipitate may be made by pure marine acid. 2. When it is made by common salt, or other salt containing marine acid, two decompositions happen, and two new combinations are formed. The nitrous acid, which was originally united with the mercury, combines with the substance that was united with the marine acid, and forms a new nitrous salt, which remains dissolved in the liquor. When common salt



salt is employed, cubic nitre is formed. If marine salt with an earthy basis is used, the liquor after the precipitation contains a nitre with earthy basis. Upon this subject, see the article *AFFINITY*. 3. All the mercury, though entirely separated from nitrous acid, and united with marine acid, is not precipitated on the present occasion, because it is reduced to a saline compound essentially soluble in water; and consequently the liquor contains as much of it as it can dissolve, and another part of it is dissolved by the water employed to wash it.

Lemeri gives another process for making a white precipitate, which consists in dissolving four ounces of sal ammoniac in a pound of water; to which is to be added an equal quantity of corrosive sublimate; all which could not be entirely dissolved alone in that quantity of water, but may by means of the sal ammoniac. See *SUBLIMATE (CORROSIVE)* and *TINCTURE OF MERCURY*. Into this solution liquid fixed alkali is to be added till no more is precipitated. The precipitate is very white, and it has been accordingly called white precipitate by several chemists: but it ought not to be confounded with the white precipitate formed by adding marine acid or common salt to a solution of mercury in nitrous acid; for they are evidently very different.

**PRECIPITATE OF GOLD BY TIN, OR PURPLE POWDER OF CASSIUS.** This precipitate of gold may be made by several methods: but which of these is the best, has not yet been decided. The cause of this uncertainty is, that the preparation requires delicate management, and is uncertain in its result; the beauty of the colour seeming to depend on some small circumstances not yet discovered; for we find that the colour of the powder obtained frequently varies, notwithstanding the processes seem to have been the same. Macquer tried several methods. The following is that which best succeeded with him, and is nearly the same as that described by Mr. Gellert in his *Metallurgic Chemistry*.

Make an aqua regia with two parts of spirit of nitre and one part of spirit of salt; dilute this acid with an equal quantity of distilled water; add to it a small piece of Malacca tin, and let it be dissolved without heat. If the weather be cold, the time employed in this solution will be long; but this is rather an advantage than an injury. When this piece of tin is entirely dissolved, add another, and let it be dissolved in the same manner; continue to add more pieces of tin, one at a time, till the liquor has acquired a yellow colour, and almost ceases to act upon the tin; then decant the liquor from the remaining piece of metal.

Also dissolve gold of twenty-four carats in aqua regia composed of three parts of spirit of nitre, and one part of spirit of salt. This solution may be accelerated by the heat of a sand-bath.

Dilute the solution of tin in a hundred times its quantity of distilled water. Try your solutions in the following manner: take a small quantity of the diluted solution of tin; divide it into two parts; to one of which add a known quantity of distilled water: to each of these proportions of the solution of tin add a drop of the solution of gold, by which they will acquire a red purple colour: observe which of the colours of the two solutions is the finest, and keep to that degree of dilution for the rest of the solution of tin: to the solution of tin thus diluted add such a quantity of the solution of gold, that there shall be in the mixture two parts of the former metal to one of the latter: stir well the mixture (which ought to be made in a large glass vessel) with a glass rod. The whole will acquire the colour of red wine, and a sediment will gradually be deposited of the same colour, while the liquor will become clear. Then pour into this clear liquor some drops of the solution of tin, and observe if any more gold is precipitated: when the

liquor is very clear, decant it gently from the sediment, which is to be well washed with pure distilled water. This is precipitate of gold, or the purple powder discovered by Cassius. It is a valuable preparation, because it is the only one known capable of giving a red purple or crimson colour to glass, enamel and porcelain. When it is to be used, it must be well mixed, and ground with a fusible glass, as Venice glass; and this mixture is to be exposed to the degree of heat necessary for melting the glass. If a coloured glass or artificial ruby be required to be made, so large a quantity of glass is to be added to the mixture, that the gold shall not destroy its transparency: but for enamel painting a smaller quantity of glass is required, that the colour may be intense. The particular proportions cannot be ascertained, because the intensity of the colour given by the gold is very variable.

The precipitate itself is an intimate combination of the calces of gold and tin.

In the *Novi Commentarii* of the Royal Society of Gottingen for the year 1774, there is an account of experiments made to investigate the causes of the uncertainty of success in preparing the purple precipitate of Cassius, by Jean. Christ. Polyc. Exleben. According to this author, a principle requisite for the success of this operation is, that the solution of tin should not be turbid: and as the nitrous acid in dissolving tin converts a great deal of this metal into a white calx, care must be taken, that the proportion of nitrous acid in the aqua regia employed for the solution of the two metals be not too great. A too great proportion also of marine acid is to be avoided; as this acid, when in too great quantity, blackens the surface of the tin, and thereby impedes its solution in the aqua regia. He recommends, therefore, to prepare the aqua regia by adding to aqua fortis  $\frac{1}{4}$  of its weight of spirit of salt; and if, upon adding a small piece of tin, a perfect solution takes place without exposure to heat, the acids are in due proportion; but if a black calx remains undissolved, he advises to add more nitrous acid, and if a whitish calx, more marine acid: the solution is to be performed slowly and without heat, by adding small portions of tin only at a time, till all is dissolved. He does not find it necessary that the solutions of gold and tin should be saturated, as Baumé asserts. He says that unless the solution of tin be recently prepared, it is not fit for the precipitation of the purple precipitate; that by standing a longer or shorter time, according to the vessel being well or ill stopped, it loses its dark colour, and its power of producing the purple precipitate; both which return upon adding a piece of tin. The solutions undiluted being mixed, a dark-coloured not a purple precipitate was obtained. Distilled water ought to be used. Well-water gave a violet colour, owing to the earthy particles in it.

Long cylindrical pieces of glass, called Jew's glass, are commonly sold, and much used by manufacturers of glass-toys. This glass, though perfectly colourless, yet when it is exposed to the heat and flame of a lamp, acquires a beautiful ruby colour, exactly similar to that of pure glass melted with powder of Cassius. As no other known substance but gold gives that colour to glass, we may presume that this glass contains some of that metal. Its want of colour proceeds from its having been melted in a covered pot; by means of which it is defended from flame or smoke, which seem to be necessary to give to this glass its peculiar colour.

Dr. Lewis observes, that though a purple or a ruby colour may easily, by the methods published, be applied upon glass or enamels, and introduced into the mass by fusion, the way of equally diffusing such a colour through a quantity of fluid glass is still a secret. That author says, that he has made several trials of  
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this kind, in one of which the glass was uniformly tinged of a ruby colour; and in the other various colours, as yellow, red, and brown, appeared, and were unequally diffused: but he had not discovered the circumstances upon which these differences depend. Orschal in his Treatise, Solfine Veste, gives a process by which he obtained a fine ruby glass. He directs, that the powder of Cassius should be ground with six times its quantity of Venice glass finely powdered; and that this mixture should be well mingled with a fritt consisting of equal parts of borax, nitre, and fixed alkaline salt, and four times as much calcined flint as of any of the salts: but he does not mention the proportion of the powder of Cassius to the fritt, nor in what manner the fusion is to be performed.

Kunkel says, that one part of the powder of Cassius is sufficient to give a ruby colour to twelve hundred and eighty parts of glass.

Dr. Franklin observes, that gold-leaf placed betwixt two plates of glass being exposed to an electrical shock, stained the contiguous glass with red spots, which were sunk into the body of the glass.

**PRINCIPLES.** Among the various divisions or arrangements of chemical principles, that which follows their respective degrees of simplicity must undoubtedly prove the most useful, because the more compounded bodies will easily assume a regular order when their respective principles are known and properly classed. There is however a limit in the advantages, that may be derived even from this method of division. The more we succeed in simplifying the principles of bodies, the more difficult it is to determine truly what passes in chemical operations; because these principles, when in their most distinct state, have the aerial form, and cannot therefore be managed or weighed without considerable difficulty. From this cause it is that, while we have no disputes concerning the changes of combination in grosser or less simple substances, the most eminent chemists often differ in their opinions concerning the transitions of first principles from one combination to another; and are not agreed concerning the existence of some of them. The peculiar properties of bodies may be changed, either by the addition or subtraction of some of their component parts; and it is easy to form a notion that such a change may also happen by a mere alteration in the disposition or relative arrangement of their parts, without any change in their quantities. To determine which of these events takes place, when we behold only the consequent change, is sometimes impracticable, for want of a sufficient number of facts; and in most cases the complete investigation requires the unprejudiced and patient exertion of all the powers of the mind. It appears proper therefore in an elementary arrangement, to fix our attention chiefly on the most palpable component parts of bodies, which are sufficiently simple; and where they are not the simplest to consider their principles in the analytical method.

The component parts of bodies are either,

1. Principles whose existence is doubtful: these are heat, light, and phlogiston.
2. Principles which have not been exhibited in a solid or fluid state, or dissolved in water, in any notable proportion: these are vital air, phlogisticated air, and inflammable air.
3. Water.
4. Earths.
5. Alkalis.
6. Acids.
7. Metals.
8. Mineral combustibles. See the articles respectively.
9. Parts of organized substances, whether obtained by mechanical pressure; by  
simple

simple solution in water or ardent spirit, by a gentle or a strong heat, by the action of solvents, or by spontaneous decomposition.

The only general division of bodies at present referred to in the writings of modern chemists, is that by which they are classed into three kingdoms, called the animal, vegetable, and mineral kingdoms. The kind of bodies arranged in the two first kingdoms is obvious from the terms; and all other bodies are considered as belonging to the mineral kingdom.

Alkalis, acids, and such compounds as they enter into, are distinguished generally by the name of salts. The leading character of salts is a strong tendency to combination, there being no bodies in nature which are not acted upon by some saline substance. This tendency appears in their eminent degree of solubility in water. All bodies known only by the name of salts, are soluble in less than two hundred times their weight of boiling water. The same cause produces their sapidity, or taste, which was regarded by the earlier chemists as a distinctive character of salts.

Metals are sometimes classed with combustible bodies; and, strictly speaking, they are combustible. But as none of them possess this property in such a degree as to burn away in the common air, without the co-operation of other inflammable bodies, which are necessary to maintain their high temperature; and as they possess other remarkable properties peculiar to themselves—they require to be placed in a separate class.

For another more strict general arrangement of the objects of chemistry, see the Table of Chemical Nomenclature, article Nomenclature, and also the Table of the Component Parts of Bodies in the Appendix.

PRINTERS' INK. See INK.

PRUSSIAN BLUE. See BLUE PRUSSIAN.

PUDDINGSTONE. Breccias. Stones which consist of a siliceous ground or cement (commonly petro-felix, jasper, or siliceous grit) in which pebbles of flint or agate are interspersed; if these be round or oval, they are called pudding-stones; if angular, breccias. Of the coarser sorts mill-stones are often made.

PUFF BALL. See LYCOPodium.

PULVERIZE. See POWDER.

PUMICE-STONE. Pierre Ponce, Bimstein. This seems rather a volcanic ejection than a volcanic product; its colour is gray, white, reddish-brown, or black; it is hard, rough and porous, and consists of slender fibres parallel to each other; very light, for it swims on water, and difficultly gives fire with steel. It is thought to have originally been an asbestos decomposed by the action of fire.

One hundred parts of it contain, according to Bergman, from six to fifteen of magnesia, with a very small proportion of calcareous earth; the remainder flint.

PURBECK STONE. A hard sand stone, the cement of which is calcareous.

PURIFICATION. By purification is meant any chemical operation by which substances required to be obtained pure and single, are separated from other heterogeneous matters with which they happen to be mixed.

As the several chemical agents and other matters are generally more or less confounded, and even combined with substances of different natures, and as we require in many accurate experiments that they should be very pure, we must,



therefore, apply the proper methods to give them the necessary degree of purity.

But these methods differ very much according to the nature of the substance to be purified. They must be appropriated to their peculiar natures, and also to the nature of the substances to be separated. For the several purifications, we are obliged to employ almost all the operations of chemistry. Hence many operations are only true purifications, although they are not so called. For instance, all the second distillations and sublimations called rectifications, are nothing else than purifications. They are employed for the purification of volatile substances from others that are fixed, or less volatile. In this class may be ranged the rectifications of oils of volatile spirits and salts, of ardent spirits, and even of mineral acids; and the sublimations of sulphur, of arsenic, of cinnabar, of salt of amber, of flowers of benjamin, and of sal ammoniac. See RECTIFICATION and SUBLIMATION. Also the repeated solutions, filtrations, evaporations, and crystallizations of neutral salts are only means of purifying them. See CRYSTALLIZATION. Several calcinations, and particularly those of fixed alkalis, are intended merely to purify them, by depriving them of a greasy matter or superabundant inflammable principle. See POTASH. Many solutions and precipitations by the humid way, particularly in the operations of parting, and of luna cornea, are performed for the purification of the perfect metals from their allay. Lastly, the repeated fusions of metallic substances, the smelting of ores, cupellations and refining, are true purifications of metallic matters. Amongst all these operations but a very few are called purifications: such as the purification of silver by nitre, of gold by antimony; of both which we shall now treat.

**PURIFICATION OF SILVER BY NITRE.** The silver to be purified by nitre is to be first granulated, and then mixed with a fourth part of its weight of dry nitre, an eighth part of pot-ash, and a little common glass, all in powder. This mixture is to be put into a good crucible, two-thirds of which only must be full. This crucible is to be covered with a smaller crucible inverted, and luted to the former, and in the bottom of which a small hole has been made. The crucibles thus disposed are to be placed in a furnace, capable of drawing air sufficiently to make the fire intense enough only to melt the silver. Then charcoal is to be put into the furnace to such a height, that only the top of the inverted crucible shall be uncovered. The coal is then to be kindled, and the vessels to be made moderately red: a hot coal ought to be put upon the small hole in the bottom of the inverted crucible. If a shining light be observed round this coal, and a slight hissing noise be at the same time heard, we may know that the operation proceeds well. The fire must be sustained at the same degree till these appearances cease; when it must be increased so that the silver be well melted, and then the crucibles are to be taken out of the furnace. The larger crucible is to be broken when it is cold, and the silver will be found at the bottom covered with a green alkaline scoria. If the metal be not sufficiently pure and ductile, the operation must be again repeated.

This operation is founded on a property which nitre has of effectually calcining all imperfect metals; and also upon a property of calcined metals by which they cannot be united with others in their metallic state. This being established, when silver allayed with copper or other imperfect metals is to be treated with nitre, this salt quickly calcines these imperfect metals by detonating with them; and they are no sooner calcined, than they are rendered incapable of remaining united with the silver. These metallic calxes being also specifically lighter, rise  
above

above the silver, where they meet the alkalised nitre and pot-ash, with both which they form a scoria. The silver being capable of resisting the action of the nitre, is thus disengaged from its alloy, is fused, and collected at the bottom of the crucible.

As the purification of silver is effected by the detonation of nitre with the imperfect metals, and as this detonation is always accompanied with swelling and effervescence, the crucibles must not be too firmly closed, otherwise the effervescence might break them, and some of the contained matter might be lost: therefore a small hole is left in the upper crucible, which serves as a cover to the other; besides, the empty space left in the vessels thus disposed, allows the matter contained to swell a little without loss.

This small hole is also very useful to shew the proper degree of fire, during the operation, as has been said. The light and the hissing noise which may be perceived when a coal is applied, are occasioned by vital air extricated from the nitre, by the decomposition of part of its acid at that violent heat. When these effects are too considerable, and that a sensible hissing may be heard at the small hole, even when a hot coal is not applied to it, we may know that the detonation is too violent. In that case the fire must be lessened, otherwise much of the nitre would sublime or be driven off, and together with it some part of the silver would be wasted. And even notwithstanding all the precautions that can be used, this operation can scarcely be performed without some loss of the silver. Small grains of silver are always to be seen in the upper crucible, and about the small hole in it. This inconvenience prevents the operation from being employed to determine the value of the silver, for which purpose cupellation is therefore used. See SILVER, NITRE, and DETONATION OF NITRE.

**PURIFICATION OF GOLD BY ANTIMONY.** To purify gold from its alloys, by antimony, the gold is to be melted in a crucible large enough to contain thrice the quantity of metal. When the gold is melted, twice its weight of crude antimony powdered is to be thrown upon it; the crucible is to be covered, and the matter left some minutes in fusion: after which, when the mixture is well fused, and so hot that its surface sparkles, it is quickly to be poured into an iron cone previously heated and greased. By striking the cone against the ground, the descent of the regulus will be assisted; and when the cone is cold, it is to be inverted, and the matter taken out. This matter consists of two substances; the upper one of which is composed of the sulphur of the antimony united with the metals with which the gold was alloyed, and the lower is the gold united with a quantity of the regulus of antimony proportionable to the quantity of metals which have been separated from the gold, and which are now united with the sulphur of the antimony. This regulus of gold may be separated from the sulphurated metals which cover it, and will be found to be so much less yellow, that is, mixed with so much more regulus of antimony, as the gold was more alloyed.

As a single fusion is not generally sufficient to disengage the gold from all its alloy, it ought to be fused again in the same manner, and with the same quantity of antimony, and even a third time, if the gold was much alloyed. It is fusible with less fire the second and third time than the first, from the regulus of antimony which is united with it.

This first part of the purification of gold by antimony is founded on a property of sulphur, by which it is incapable of uniting with gold, and is strongly disposed to unite with all other metallic substances, excepting platina and zinc;



and also upon this property of sulphur, that it has less affinity with regulus of antimony than with any metallic substance with which it can unite. Hence, when gold allayed with silver, copper, iron, lead, &c. is fused together with crude antimony, these latter metals unite with the sulphur of the antimony, while the reguline part, disengaged by them from its sulphur, unites with the gold. The separation of metals from gold is then really occasioned by the sulphur of the antimony. This purification of gold is consequently a kind of dry parting, but it succeeds better than the dry parting by sulphur alone. The reason of this difference is, that sulphur being very volatile and inflammable is in great measure dissipated and consumed, when it is employed alone, before it can seize the metals allayed with the gold; whereas, when it is already united with a metallic substance, as it is in the antimony with the reguline part, which prevents it from being quickly consumed and dissipated, it may be much more easily applied to the metallic substances allayed with gold. Notwithstanding this advantage, as a quantity of regulus of antimony is always united with the gold, proportionable to the quantity of metallic substances separated by means of the sulphur of the antimony; and as the separation of this regulus from the gold requires much time; therefore, when we would purify gold that is much allayed, suppose under sixteen carats, we ought to add along with the antimony some pure sulphur, that we may have a less quantity of regulus to separate afterwards from the gold.

When these first fusions have been well made, the gold obtained is allayed with only regulus of antimony. But as this semi-metal is very volatile and very combustible, it may be separated from the gold by a sufficiently long exposure to the action of fire. For this purpose the regulus of gold obtained by the former operation is to be put into a large crucible, and heated sufficiently to keep it in good fusion. With this heat, the antimony will be dissipated into smoke. If the heat be too strong, some of the gold will be carried off with the antimony. The operation therefore must be performed slowly; and it continues a long time when much of the regulus of antimony is united with the gold; but it may be abridged by blowing on the surface of the metallic mass, which greatly assists in the calcination and evaporation of all bodies, and particularly that of the regulus of antimony. When a part of the regulus is dissipated, more heat is required to keep the metal fused, and therefore the fire must be increased towards the end of the operation: besides, when only a small quantity of regulus of antimony remains, it is so covered by the gold, and protected from the action of the fire and air, that a stronger heat is necessary to evaporate it. The smoke ceases entirely towards the end of the operation, although some regulus still remains united with the gold. The purification is completed by means of a little nitre thrown into the crucible, which effectually calcines the remaining regulus of antimony. Sometimes, after these operations, the gold is found to be deprived of much of its usual ductility, which however is easily restored to it by fusing it with nitre and borax.

The ancient chemists called antimony the *balneum regis*, or the *balneum solis*, and the *lupus metallorum*, from this property which it possesses of purifying gold. The sulphur of this mineral does, indeed, seize almost all the metals with which gold can be allayed; but these metals are not destroyed, but only reduced to a sort of mineral state by the sulphur, forming the scoria, from which they may be obtained. Therefore, when the gold contained much allay of silver, the scoria is very valuable, since it contains all the silver which was united with the gold.

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This scoria ought to be preserved and treated like an ore of silver, and thus the metal extracted from it. See PARTING.

**PURPLE DYE.** By the mixture of red and blue, we obtain violet, purple, dove colour, pansy, amaranth, lilac, mauve, and a great number of other shades, determined by the nature of the substances the red colour of which is combined with the blue, by the proportion of these substances, and the different steps of the process.

According to Hellot's observations, stuff which has been dyed scarlet, takes an unequal colour when blue is to be united with it. The blue is therefore given first, which even for violet and purple ought not to be deeper than the shade distinguished by the name of sky-blue: a boiling is given with alum mixed with two-fifths of tartar, the stuff is then dipped in a bath composed of nearly two-thirds as much cochineal as for scarlet, to which tartar is always added. The circumstance which distinguishes the process for purple from that for violet, is, that for the former, a lighter blue ground is given, and a larger proportion of cochineal is employed. These colours are frequently dyed after the reddening for scarlet, such quantities of cochineal and tartar being added as are thought necessary. The operation is conducted in the same manner as for scarlet.

Lilacs, pigeons-necks, mauves, &c. are commonly dipped in the boiling which has served for violet, after alum and tartar have been added to it; the blue ground having been proportioned to the shade required: the quantity of cochineal is also adjusted in a similar manner: a little solution of tin is added for some reddish shades, such as peach blossom. It must be observed, that though the quantity of cochineal is diminished according to the lightness of the shade required, the quantity of tartar is not lessened, so that the proportion of it compared with that of the cochineal is so much the greater, as the colour required is lighter.

Mr. Poerner is of opinion, that to obtain the colours composed of red and blue, it is advantageous to employ the solution of indigo in sulphuric acid, because a greater variety of shades is thus more easily procured, and the process is shorter and less expensive. The colours obtained in this way are indeed much less durable than when the blue vat is employed; but Mr. Poerner asserts, that they possess durability, when solution of indigo to which alkali has been added is employed.

He prepares a pound of cloth with three ounces of alum, by boiling it for an hour and an half, and leaving it a night in the liquor after it is cold. He makes the bath with an ounce and an half of cochineal, and two ounces of tartar, boiling it for three-quarters of an hour; and then adding two ounces and a half of solution of indigo, he stirs it, and makes it boil gently for a quarter of an hour: he thus obtains a very beautiful violet.

For the different shades which result from the mixture of red and blue, according as one or other of the colours prevails, he increases or diminishes the proportion of the solution of indigo; he increases it as far as five ounces, and diminishes it to five drams for each pound of cloth: he also reduces the quantity of cochineal, but never below an ounce, because the colour would become too dull: he changes the proportion of tartar, and finally, he varies the preparation given to the cloth, by the addition of tartar or solution of tin in different quantities.



In silk, two kinds of violets are distinguished, the fine, and the false: the last is made either with archil, or brazil-wood.

For fine violet the stuff is first passed through cochineal, and afterwards dipped in the vat; the silk is prepared and dyed in the cochineal in the same manner as for crimson, except that neither tartar nor solution of tin, which serve to heighten the colour, are employed. More or less cochineal is used, according to the intensity of the shade required. The common proportion for a fine violet, is two ounces for each pound of silk. When the silk is dyed, it is washed at the river and beetled twice, then dipped in a vat of greater or less strength, according to the depth we wish to give the violet; lastly, it is washed and dried with the precautions which are proper for all colours dyed in the vat. To give greater strength and beauty to the violet, it is commonly passed through the archil bath; and this custom, which is frequently abused, is indispensable for the light shades, the colour of which would otherwise be too dull.

When the silk has been dyed with cochineal as above directed, a very light blue shade must be given to it for purple; only the deepest shades are dipped in a weak vat; such as are less deep are only dipped in cold water, into which a little of the liquor of the vat has been put, because they would take too much blue in the vat itself, though ever so weak. The light shades of this colour, such as gilly-flower, gridelin, and peach-blossom, are made in this way, by diminishing the proportion of cochineal.

The false violets in silk are produced in many different ways; those which are most beautiful, and most in use, are prepared with archil. The strength of the archil bath is adapted to the colour we wish to obtain; the silk is turned in it on the skein-sticks, after having been beetled at the river after scouring: when the colour is thought to be sufficiently deep, a pattern is tried in the vat, to see whether it takes the violet we wish for. If the shade is found to be of the proper depth, the silk is beetled at the river and dipped in the vat as for the fine violets; less of the blue, or less of the archil colour are given, according as we mean that the violet should incline to red or blue.

According to Mr. Gühliche, beautiful violets may be produced in silk by means of the solution of indigo; but they possess little durability, and become reddish, because the colour of the indigo fades first.

A pound of silk is soaked in a bath composed of two ounces of alum and two ounces of solution of tin, after being decanted from the sediment formed in the mixture. The dye bath is prepared with two ounces of cochineal (reduced to powder with a dram of tartar) and the remainder of the bath which has served as mordant, with the addition of a sufficient quantity of water; after a slight boiling, such a quantity of solution of indigo is added, as gives the bath a proper shade of violet; the silk is then immersed, and boiled until it has acquired the proper shade, when it is wrung, washed in a stream, and dried in the shade, like all delicate colours. The bath is exhausted by the light shades.

A violet is given to silk, by dipping it in water with which verdgris has been mixed, instead of aluming it, and then giving it a bath of logwood, when it assumes a blue colour, which is changed to violet, either by adding alum to the bath, or by dipping it in a weaker or stronger solution of alum, which gives the particles of logwood a red colour. It is unnecessary to observe, that this violet is of a very fading nature, and only a moderate degree of beauty. One possessing much greater beauty, and to which a considerable degree of intensity may be added,

is made by dipping the alumed silk in a bath of brazil-wood, and again, after it has been washed at the river, in a bath of archil. Madder is also employed in dyeing cloth, after it has had a blue ground; couleur de roi, minime, and obscure amaranth, are thus obtained; galls are commonly added to the madder, and for the light shades, brazil-wood; for the deep shades, more or less browning is given, with a solution of vitriol of iron. These colours are rendered more beautiful by the addition of kermes, or more especially of cochineal.

By employing solution of indigo with madder, in the same way as with cochineal, we may, according to Mr. Poerner, obtain brown colours inclining the more to red, the less solution of indigo we employ; alum and tartar may serve for the preparation, but alum must not be put into the bath.

Mr. Poerner employs brazil-wood and solution of indigo, to obtain different colours, which incline more or less to blue and red, by a process similar to that pointed out for cochineal and madder. These are beautiful, but durability cannot be expected in colours obtained by such means. The substances which render them most fixed, are vitriolated lime, vitriol of zinc, or white vitriol, and acetite of copper, or crystallized verdegis, which must be added to the bath.

Logwood is also employed to make sloe, damascene, purple and other shades. This wood, with the addition of galls, very easily communicates all these colours to wool previously dyed blue. When we wish to brown them, a little vitriol of iron is employed, and by this means we produce shades, which are much more difficultly obtained from durable ingredients, but they possess little stability: durable colours which have been highly esteemed, have however been obtained from brazil and logwood. Berthollet, from whose art of dying the present article is extracted, was indebted to Mr. Decroizille, for the following particulars of the process employed, which he gives in the words of the author.

M. Giros de Gentilly is the first who succeeded in France, in obtaining a durable dye from violet-wood fixed by solution of tin. His first essays were made at Louviers, with Messrs. Petou, nephew, and Frigard, about twelve years ago. From what he had suffered to transpire respecting the substances which composed his mordant, I succeeded in imitating him tolerably well. I made a solution of tin in sulphuric acid, to which I then added muriat of soda, red acidulous tartrate of potash, and sulphat of copper. My success was so great as to induce M. Giros to offer me a partnership in the very lucrative trade in this article, which he carried on at Louviers, Elboeuf, Abbeville, Sedan, and the Pays de Liege. M. Giros then taught me a much more convenient mode of forming this compound; it consists in making a solution of tin in a mixture of sulphuric acid, muriat of soda, and water; to this solution, the tartrate and sulphat are added, in the form of powder. Of this mordant we made no less than fifteen hundred quarts in twenty-four hours, in a single leaden vessel moderately heated. We carried on a very profitable trade in this article at the rate of thirty sols (fifteen pence English) per pound for three years, since which time it constantly declined, until we lost it altogether; the reason of which was this: M. Giros having suffered his secret to transpire, we had a number of imitators, who at first succeeded in a less degree, but afterwards better than ourselves. In a compound consisting of so many ingredients as this, in an operation which is still so obscure as that whereby colours are fixed, it is almost impossible to arrive at perfection by any other means than random trials, which may be infinitely varied



varied by the different proportions, and more especially by the *modus agendi*, and to a much greater extent, than chemists who had bestowed less time on this subject than I have done, would suppose. I am therefore not ashamed to confess, that I was forced to abandon the business, while I saw, and still see, those who are no chemists deriving a very comfortable profit from it. What determined me to abandon it altogether, was the invention of the new process for bleaching linen, to the improvement of which I have almost entirely devoted myself.

Having given you the history of the mordant for the *prune de Monsieur*, I shall mention the mode of employing it, and its effects.

If it is wool in the fleece which is to be dyed, one-third of its weight of mordant is required; if it is a stuff, only one-fifth is necessary. A bath is prepared of a degree of heat which the hand can bear, with which the mordant is well mixed, and the wool or stuff dipped in it and properly stirred, the same degree of heat being kept up for two hours, and even increased a little at last; it is then taken out, aired, and very well washed: a fresh bath of pure water at the same heat is prepared, a sufficient quantity of the decoction of violet wood is added; the stuff immersed, stirred, and the fire increased to a boiling heat, which is continued for a quarter of an hour: the stuff being then taken out, aired, and carefully rinsed, the dyeing is finished. If the decoction of one pound of violet wood of Campeachy has been employed for three pounds of wool, and a proportionate quantity for stuffs, which require less, a fine violet is produced, to which a sufficient quantity of brazil-wood gives the shade commonly known by the name of *prune de Monsieur*.

The colouring substances which are capable of being advantageously fixed on wool by this mordant, are those of violet and red logwood (logwood and brazil), and fustic (*bois de fusset*). *Bois jaune* (*morus tinctoria*) also affords tolerable colours. The colour which is thus given by violet and red wood is liable to be changed in the fulling, by means of the soap or the urine employed; and this change, which is always produced by alkaline substances, is remedied by a bath very slightly acid, and a little hot, called brightening, for which the sulphuric acid is preferred. The colour comes out as deep and oftener brighter than before the change. Wools dyed by means of this mordant, admit of being spun into a more beautiful and finer thread than when alum has been employed. By leaving out the sulphat of copper, more beautiful colours are obtained from fustic and yellow wood, as well as from weld. Madder gives an orange red colour, but less deep than with an equal quantity of alum; the omission of the sulphat of copper renders the wool much more harsh, and besides, the mordant thus prepared gives but indifferent colours with violet, and more especially with red wood. One of the great defects of this mordant before it was improved, was, and frequently still is, to render the colours uneven; whenever they are uniform, they turn out always very beautiful, harmless, and soft. This process succeeds equally well on silk. By substituting acetite of lead for sulphat of copper, it succeeds tolerably well in cotton and thread previously galled. The employment and conveyance of this mordant are inconvenient, on account of the heavy sediment which half fills the vessel, under a corrosive liquor which can only be kept in stone-ware. I have, however, found a remedy for these inconveniences, by omitting the water in the receipt, by which means I have only a kind of paste, the use of which is more convenient, and the carriage two-fifths cheaper. Now that common salt is cheap (in France), I may possibly return to the employment of furnishing our dyers with this mordant, of a better quality, in my opinion, than  
that

that with which they are supplied, and more especially at a much cheaper rate; but I must first devote some more time to the composition and employment of your lixivium.

Here ends the account of Mr. Decroizille.

The most common method of dyeing thread and cotton, violet, is first to give them a blue ground in the vat, proportionate to the shade we want, and to dry them; they are then galled, in the proportion of three ounces of galls to a pound: they are left for twelve or fifteen hours in this gall bath, after which they are wrung and dried again. The thread and cotton are then passed through a decoction of logwood, and when well soaked are taken out, and two drams of alum, and one dram of dissolved verdegris for each pound of thread and cotton, are added to the bath; the skeins are then re-dipped on the skein-sticks, and turned for a full quarter of an hour, when they are taken out to be aired; after which they are again completely immersed in the bath for a quarter of an hour, then taken out and wrung. Lastly, the vat which has been employed is emptied; half of the decoction of logwood which had been reserved is poured in, two drams of alum are added, and the thread dipped afresh, until it is brought to the shade required. The decoction of logwood ought to be stronger or weaker according to the shade we want: this violet stands the action of the air tolerably well, but cannot be compared in durability to that obtained by means of madder, for which see that article.

In the production of violet by cochineal, it may be observed, that the woollen stuff has been disposed to take a crimson, by the bath, which contains alum; but the tartar added to the dye bath brings the colour back to red; this is a general property of all acids.

For purple, the red is rendered a little more predominant, by increasing the quantity of the cochineal, and diminishing the intensity of the blue ground.

The shades bordering on these two colours should have a more distinct red, and the same proportion of tartar is preserved, though that of cochineal and the depth of the blue ground are diminished.

For silk, the tartar is omitted: it naturally acquires from cochineal a colour, to which it is only necessary to add a slight blue shade to produce purple; a deeper blue shade gives a violet colour; but to increase the fulness of the violet and give it brightness, archil must be employed.

When the solution of indigo in sulphuric acid is used, the sulphuric acid acts in different ways on the red substance employed; it produces little change in the colour of cochineal, already disposed to a crimson tinge by the aluming; but it should give a fawn colour to madder, upon which acids readily produce this effect; and it does not seem probable, that that substance could be employed with advantage in this process; it is better to employ it in dyeing stuff which has already received a blue ground. Brazil and logwood too seem ill adapted to produce fine colours with the sulphuric solution of indigo, because acids also change them yellow, though in a less distinct degree; but they retain their red colour, as already observed, when their colouring particles are precipitated by calx of tin.

Berthollet offers the following explanation of the process of M. Decroizille, after expressing his diffidence to hazard an opinion unsupported by direct experiment, on so complicated a process.

The sea salt is decomposed by the sulphuric acid, and the muriatic acid thus set at liberty dissolves the tin; a part of the tin is precipitated by the acid of



tartar, producing the sediment which has been noticed. The calx of copper forms the blue with the colouring particles of the logwood; the calx of tin produces violet with the same wood, and red with the colouring particles of the brazil-wood.

As the liquor retains an excess of acid, it might perhaps be useful to substitute crystals of verdegris to the vitriol of copper, because then the free acid would have less activity; perhaps it might be still better to employ mere verdegris, because that part of the calx of copper which is uncombined in it, would unite with the excess of acid, by which means less acid would remain in the liquor; perhaps the quantity of tartar should be diminished, because less of the tin would then be precipitated.

**PUTREFACTION.** Every living body, when once deprived of life, performs a retrograde process, and becomes decomposed. This decomposition is called fermentation in vegetables, and putrefaction in animal substances. The same causes, the same agents, and the same circumstances, determine and favour the decomposition of vegetables and animals, and the difference of the productions which are obtained arises from the difference of the constituent parts of each\*.

Air is the principal agent of animal decomposition, but water and heat prodigiously facilitate its action. "*Fermentatio ergo definitur quod sit corporis densioris rarefactio, particularumque aërearum interpositio: ex quo concluditur debere in aëre fieri nec nimium frigido, ne rarefactio impediatur; nec nimium calido, ne partes raribiles expellantur.*" Becher, *Phys. Sub. lib. i. f. 5. p. 313.* edit. Francofurti.

An animal substance may be preserved from putrefaction by depriving it of the contact of the air; and this process may be accelerated or retarded by varying or modifying the purity of the same fluid.

In those circumstances wherein we see putrefaction developed without the contact of atmospherical air, the effect is produced by the water which impregnates the animal substance, becomes decomposed, and affords the element and the agent of putrefaction. Hence no doubt it arises that putrefaction is observed in flesh closed in a vacuum. See Lyons, *Tentamen de Putrefactione*.

Moisture is likewise an indispensable requisite to facilitate putrefaction; and any substance may be defended from this change by completely drying it. This was performed by Villaris and Cazalet of Bourdeaux, by means of stoves. The meat thus prepared was preserved for several years without having contracted any bad flavour. The sands and light porous earths preserve the bodies of men only by virtue of the property of exhausting their juices, and drying the solids. From this cause it is that entire caravans have been discovered in Arabia, consisting of men and camels perfectly preserved in the sands under which the impetuous winds have buried them. In the library of Trinity College Cambridge, in England, a human body may be seen perfectly preserved, which was found under the sand in the island of Teneriffe. Too much humidity impedes putrefaction, according to the observation of the celebrated Becher: "*Nimia quoque humiditas a putrefactione impedit, prout nimius calor; nam corpora in aqua potius gradatim consumi quam putrescere, si nova semper affluens sit, experientia docet: unde longo tempore integra interdum submersa prorsus a putrefactione immunia vidimus; adeo ut nobis aliquando speculatio occurreret, tractando tali modo cadavera anatomiz subjicienda, quo diutius a foetore et putrefactione immunia forent.*" *Phys. Sub. lib. i. f. 5. cap. 1. p. 277.*

\* The general part of this article is from Chaptal.

In order, therefore, that a body may putrefy, it is necessary that it should be impregnated with water, but not that it should be inundated. It is likewise necessary that this water should remain in the texture of the animal body, without being renewed. This condition is requisite, 1st, To dissolve the lymph, and to present to the air the most putrescible substance with the greatest extent of surface. 2d, In order that the water may itself become decomposed, and by this means afford the putrefactive principle. Putrefaction is retarded and suspended by baking, because the flesh is dried, and by that means deprived of the humidity, which is one of the most active principles of its decomposition.

A moderate degree of heat is likewise a condition favourable to the animal decomposition. By this heat the affinity of aggregation between the parts is weakened, and consequently they assume a stronger tendency to new combinations. Hence it arises that flesh meat keeps longer during the winter than the summer, and better in cold than in hot countries. Becher has given a very intelligent sketch of the influence of temperature on animal putrefaction: "*Aër calidus et humidus maximè ad putrefactionem facit . . . . . corpora frigida et sicca difficulter, imò aliqua prorsus non putrescunt; quæ ab imperitis pròinde pro sanctis habita fuere. Ita aër frigidus et ficcus, imprimis calidus et ficcus, a putrefactione quoque præservat; quod in Hispania videmus, et locis aliis calidis, sicco-calido aëre præditis, ubi corpora non putrescunt et resolvantur; nam cadavera in oriente in arena, imò apud nos arte in furnis, siccati et sic ad finem mundi usque a putredine præservari, certum est: intensum quoque frigus a putredine præservare; unde corpora Stockholmiae tota hyeme in patibulo suspensa sine putredine animadvertimus.*" *Phyf. Sub. 1. i. cap. 1.*

Such are the causes which are capable of determining and favouring putrefaction; and hence we may perceive the best means of preventing, increasing, or modifying it at pleasure. A body will be preserved from putrefaction by depriving it of the contact of atmospherical air; for this purpose nothing more is required than to place the body in a vacuum, or to envelop it in a covering which may defend it from the immediate action of the air; or else to envelop it in an atmosphere of some gaseous substance which does not contain vital air. We shall observe, on this subject, that the effects observed in flesh exposed in the fixed air, nitrous air, &c. are referable to a similar cause; and it appears to Chaptal, that it is without sufficient proof that a conclusion has been drawn that these same gases, internally taken, ought to be considered as antiseptic; because, in the cases we have mentioned, they act only by defending the bodies they surround from the contact of vital air, which is the principle of putrefaction. Putrefaction may be favoured by keeping bodies at a suitable temperature. A degree of heat from sixty-five to ninety degrees diminishes the adhesion of the parts, and favours the action of the air: but if the heat be greater it volatilizes the aqueous principle, dries the solids, and retards the putrefaction. It is necessary therefore, for the decomposition of an animal—1st, That it have the contact of atmospheric air; and the purer this air is, the more speedy will be the putrefaction. 2. That it be exposed to a moderate degree of heat. 3. That its texture be impregnated with humidity.—The experiments of Pringle, Macbride, and Gardane have likewise shewn us, that putrefaction may be hastened by sprinkling the animal substances with water containing a small quantity of salt; and it is to a like cause that we ought to refer several processes used in kitchens to produce this effect in food, as well as in the preparation of cheese, the curing of tobacco, the making of bread, &c.



Becher expresses himself as follows on the causes which produce putrefaction in living bodies:—"Causa putrefactionis primaria defectus spiritus vitalis bal-  
samini est; secundaria, deinde, aer externus et ambicus, qui interdum adeo  
putrefaciens et humidus-calidus est, ut superstitem in vivis etiam corporibus bal-  
saminum spiritum vincat, nisi confortando augeatur; ex quo colligi potest, pre-  
servantia a putredine subtilia ignea oleosa esse debere."—This celebrated chemist  
concludes, from the same principles, that ligatures, copious bleedings, or any  
debilitation whatever, determines putrefaction. He likewise thinks that astrin-  
gents oppose putrefaction only by condensing the texture of the animal parts; for  
he considers rarefaction or relaxation as the first effect of putrefaction. He  
thinks that spirituous liquors act as anti-putrescent merely by animating and  
stimulating the vis vitæ. He affirms that the use of salted meats, which  
heat much, assisted by the moisture very common in ships and sea-ports, pro-  
duces the scurvy; and he observes, with reason, that the tendency and effect of  
putrefaction are diametrically opposite to those of generation: "nam sicut in gene-  
ratione partes coagulantur et in corpus formantur, ita in putrefactione partes  
resolvuntur et quasi informes fiunt."

As the phenomena of putrefaction vary according to the nature of the sub-  
stances themselves, and the circumstances which accompany this operation, it  
follows, that it must be very difficult to describe all the phenomena which it ex-  
hibits. We shall therefore endeavour to trace only those which appear to be  
most constant.

Every animal substance exposed to the air at a temperature above ten degrees  
of Reaumur, and moistened with its own serous humour, putrefies; and the pro-  
gress of this alteration appears in the following order:

The colour first becomes pale; its consistence diminishes; its texture becomes  
relaxed; the peculiar smell of fresh meat disappears, and is succeeded by a faint  
and disagreeable smell. The colour itself at this time inclines to blue; as we see  
in game which begins to turn, in wounds which fall into suppuration, in the va-  
rious parts threatened with gangrene, and even in that putrefaction of the curd  
which forms cheese. Most of our food suffers the first degree of putrefaction before  
we use it.

After this first period the animal parts become more and more softened, the  
smell becomes fetid, and the colour of an obscure brown; the fibrous part easily  
breaks; the texture becomes dry, if the putrefaction be carried on in the open  
air; but the surface becomes covered with small drops of fluid, if the decompo-  
sition be made in vessels which oppose its evaporation.

To this period succeeds that which most minutely characterizes animal putre-  
faction. The putrid and nauseous smell which was manifested in the second degree,  
becomes mixed with a smell of a more penetrating kind, arising from the disen-  
gagement of ammoniacal gas: the mass becomes still less and less consistent.

The last degree of decomposition has its peculiar characters. The smell be-  
comes faint, nauseous, and exceedingly active. This, more especially, is con-  
tagious, and transmits the seeds of infection to a great distance: it is a true fer-  
ment, which deposits itself upon certain bodies, to appear again at long inter-  
vals. Van Swieten reports, that the plague having appeared at Vienna in 1677,  
and having again appeared in 1713, the houses which had been infected at its  
first appearance were likewise infected at the second. Van Helmont asserts  
that a woman contracted an anthrax at the extremity of her fingers, in conse-  
quence of having touched papers impregnated with pestilential virus. Alex-  
ander

ander Benedictus has written, that pillows reproduced the contagion seven years after having been infected; that cords had remained infected for thirty years, and likewise communicated it, according to Faustus. The plague at Messina was for a long time concentrated in the warehouses where merchandize was inclosed with the suspected bales. Mead has transmitted the most alarming facts concerning the durable impression of contagion.

When the putrefying substance is in its last stage, the fibrous texture is scarcely discernible, and has no longer any appearance but that of a soft, disorganized and putrid mass. Bubbles are seen to escape from the surface of this matter; and the whole ends by its drying, and becoming reduced to an earthy matter, which is friable when taken between the fingers.

We do not speak of the production of worms; because it appears to be proved that they owe their origin only to the flies which endeavour to deposit their eggs upon such bodies as are best suited to support the young they contain. If flesh meat be well washed, and left to putrefy under a sieve, it will pass through all the degrees of putrefaction without the appearance of worms. It has been observed that worms are of a different species, according to the nature of the disease, and the kind of animal which putrefies. The exhalation which arises from bodies in these different cases, attracts different species of insects, according to its nature. The opinion of those who believe in spontaneous generation appears to Chaptal to be contrary to the experience and wisdom of nature, which cannot have committed the reproduction and number of the species to chance. The progress of nature is the same for all the classes of individuals; and since it is proved that all the known species are re-produced in one and the same manner, how can we suppose that nature departs from her plain and general laws for the small number of individuals whose generation is less known to us?

Becher had the courage to make observations, during the course of a year, upon the decomposition of a carcase in the open air; and to observe all the phenomena. The first vapour which rises, says he, is subtile and nauseous: some days after it has a certain sour and penetrating smell. After the first weeks, the skin becomes covered with a down, and appears yellowish; greenish spots are formed in various places, which afterwards become livid and black; a thick mossy or mouldy substance then covers the greatest part of the body; the spots open, and emit a sanies.

Carcases buried in the earth present very different phenomena; the decomposition in a burying-ground is at least four times as slow. It is not perfectly ended, according to Mr. Petit, till three years after the body has been interred, at the depth of four feet; and it is slower in proportion as the body is buried at a greater depth. These facts agree with the principles which we have already established for bodies buried in the earth, and subjected to laws of decomposition very different from those which take place in bodies exposed to the open air. In this case the decomposition is favoured by the waters which filter through the earth, and dissolve and carry with them the animal juices. It is also favoured by the earth, which absorbs the juices with more or less facility. Messrs. Lemery, Geoffroy, and Hunaud have proved that argillaceous earths exert a very slow action upon bodies; but when the earths are porous and light, the bodies then dry very speedily. The several principles of bodies absorbed by the earth, or carried by the vapours, are dispersed through a great space, imbibed by the roots of vegetables, and gradually decomposed. This is what passes in burying-grounds in the open air; but it is very far from being applicable to the sepulchres

which.



which are made in churches and covered places. Here is neither water nor vegetation; and consequently no cause which can carry away, dissolve, or change the nature of the animal fluids: and it is an instance of wisdom in the French government, that has prohibited the burying in churches; a practice which was once a subject of horror and infection.

The accidents which have happened at the opening of graves and vaults are but too numerous, to render any apology necessary for our speaking a few words respecting the method of preventing them.

The decomposition of a body in the bowels of the earth can never be dangerous, provided it be buried at a sufficient depth, and that the grave be not opened before its entire and complete decomposition. The depth of the grave ought to be such that the external air cannot penetrate it; that the juices with which the earth is impregnated may not be conveyed to its surface; and that the exhalations, vapours, or gases, which are developed or formed by decomposition, should not be capable of forcing the earthy covering which detains them. The nature of the earth in which the grave is dug, influences all its effects. If the stratum which covers the body be argillaceous, the depth of the grave may be less, as this earth difficultly affords a passage to gas and vapour; but in general it is admitted to be necessary that bodies should be buried at the depth of five feet, to prevent all these unhappy accidents. It is likewise necessary to attend to the circumstance, that a grave ought not to be opened before the complete decomposition of the body. This decomposition, according to Mr. Petit, is not perfect until the expiration of three years, in graves of four feet depth; or four years, when they are six feet deep. This term affords many varieties, according to the nature of the earth, and the constitution of the subjects buried in it; but we may consider it as a medium. The pernicious custom which allows a single grave to families more or less numerous, ought, therefore, to be suppressed; for in this case the same grave may be opened before the time prescribed. These are abuses which ought to occupy the attention of government; and it is time that the vanity of individuals should be sacrificed to the public safety. It is likewise necessary to prohibit burying in vaults, and even in coffins. In the first case, the principles of the bodies are spread into the air, and infect it; in the second, their decomposition is slower and less perfect.

If these precautions be neglected; if the dead bodies be heaped together in too confined a space; if the earth be not proper to absorb the juices, and decompose them; if the grave be opened before the entire decomposition of the body—unhappy accidents will, no doubt, be produced; and these accidents are but too common in great towns where every wise precaution is neglected. An instance of this happened when the ground of the church of St. Benoit at Paris was dug up a few years ago; a nauseous vapour was emitted, and several of the neighbours were affected by it. The earth which was taken out of this grave was unctuous, viscid, and emitted an infectious smell. Messrs. Maret and Navier have left us similar observations.

Boyle relates that he has preserved lemons, oranges, and other fruits from putrefaction, or other fermentation, during several years, by including them in an exhausted receiver. Doctor Macbride found that putrefaction was accelerated by enclosing a piece of flesh in an exhausted receiver; but that another piece continued sweet, which was included in an exhausted hollow brass sphere, consisting of two hemispheres joined together. He conjectures that the cause of this difference might be, that in the latter experiment the vacuum was more perfect than

than in the former, as the glass receiver did not seem to exclude with sufficient accuracy the external air; and though a partial vacuum may accelerate putrefaction, yet some air may be necessary to this process.

It is well known that bodies are preserved from putrefaction by covering them with wax, suet, &c. Whether is this effect produced merely by excluding external air, or by preventing the extrication of the gas, or both?

Sir John Pringle has made experiments to determine the powers of certain substances to promote or prevent putrefaction. From these experiments he has formed the following table, shewing the relative antiseptic powers of the saline substances mentioned. Having found that two drams of beef put in a phial with two ounces of water, and placed in a heat equal to ninety degrees of Fahrenheit's thermometer, became putrid in fourteen hours, and that sixty grains of sea-salt preserved a similar mixture of beef and water more than thirty hours, he made the antiseptic power of the sea-salt a standard, to which he compared the powers of the other salts. The algebraic character + signifies, that the substance to which it is annexed had a greater antiseptic power than is expressed by the numbers.

Sea-salt, or the standard	—	1
Sal-gem	—	1+
Vitriolated tartar	—	2
Spiritus Mindereri, or distilled vinegar saturated with volatile alkali	—	2
Soluble tartar	—	2
Sal diureticus, or muriated vegetable alkali	—	2+
Crude sal ammoniac	—	3
Saline mixture	—	3
Nitre	—	4+
Salt of hartshorn	—	4+
Salt of wormwood	—	4+
Borax	—	12
Salt of amber	—	20
Alum	—	30

N. B. The quantities of spiritus Mindereri and of the saline mixture were such, that each of them contained as much alkaline salt as the other neutral salts.

Myrrh, aloes, affaetida, and terra Japonica, were found to have an antiseptic power thirty times greater than the standard. Gum ammoniacum and sagapenum shewed little antiseptic power.

Of all resinous substances, camphor was found to resist putrefaction most powerfully. Sir John Pringle believes that its antiseptic power is 300 times greater than that of sea-salt.

Chamomile flowers, Virginian snake-root, pepper, ginger, saffron, contrayerva root, and galls were found to be twelve times more antiseptic than sea-salt.

Infusions of large quantities of mint, angelica, ground-ivy, green tea, red-roses, common wormwood, mustard, and horse-radish, and also decoctions of poppy-heads, were more antiseptic than sea-salt.

Decoctions of wheat, barley, and other farinaceous grains, checked the putrefaction by becoming sour.

Chalk, and other absorbent powders, accelerated the putrefaction, and resolved

meat



meat into a perfect mucus. The same powders prevented an infusion of farinaceous grains from becoming mucilaginous and sour.

One dram of sea-salt was found to preserve two drams of fresh beef in two ounces of water, above thirty hours, uncorrupted, in a heat equal to that of the human body, or above twenty hours longer than meat is preserved in water without salt: but half a dram of salt did not preserve it more than two hours longer than pure water. Twenty-five grains of salt had little or no antiseptic quality. Twenty-grains, fifteen grains, but especially ten grains only of sea-salt were found to accelerate and heighten the putrefaction of two drams of flesh. These small quantities of sea-salt did also soften the flesh more than pure water.

The same learned and ingenious physician made experiments to discover the effects of mixing vegetable with animal matters.

Two drams of raw beef, as much bread, and an ounce of water, being beat to the consistence of pap, and exposed to ninety degrees of heat, according to Fahrenheit's thermometer, began to ferment in a few hours, and continued in a fermentation during two days. When it began to ferment and swell, the putrefaction had begun; and in a few hours afterwards the smell was offensive. Next day the putrid smell ceased, and an acid taste and smell succeeded. Fresh alimentary vegetables, as spinach, asparagus, scurvy-grass, produced similar effects as bread on flesh, but in a weaker degree. From several other experiments he found that animal substances excite the fermentation of vegetable substances, and that the latter substances correct the putrescency of the former.

By adding saliva to a similar mixture of flesh, bread, and water, the fermentation was retarded, moderated, but rendered of twice the usual duration, and the acid produced at last was weaker than when no saliva was used.

By adding an oily substance to the common mixture of flesh, bread and water, a stronger fermentation was produced, which could not be moderated by the quantity of saliva used in the former experiment, till some fixed alkaline salt was added; which salt was found, without saliva, to stop suddenly very high fermentations.

He did not find that small quantities of the following salts, sal ammoniac, nitre, vitriolated tartar, sal diureticus, salt of hartshorn, salt of wormwood, were septic, as small quantities of sea-salt were.

Sugar was found to resist putrefaction at first, as other salts do, and also to check the putrefaction after it had begun by its own fermentative quality, like bread, and other fermentative vegetables.

Lime-water made some small resistance to putrefaction.

Port-wine, small-beer, infusions of bitter vegetables, of bark, and the juice of antiscorbutic plants, retarded the fermentation of mixtures of flesh and bread. But an unstrained decoction of bark considerably increased that fermentation.

Crabs eyes accelerated and increased the fermentation of a mixture of flesh and bread.

Lime-water neither retarded nor hastened the fermentation of such a mixture: but when the fermentation ceased, the liquor was neither putrid nor acid, but smelled agreeably.

Flesh pounded in a mortar was found to ferment sooner than that which had not been bruised.

The tough inflammatory crust of blood was found to be most putrescent, next to which the crassamentum, or red coagulated mass, and lastly the serum.

Dr.

Dr. Macbride's experiments confirm many of these above related, especially those which show that the fermentation of vegetable substances is increased by a mixture of animal or putrescent matter; that the putrescency of the latter is corrected by the fermentative quality of the former; and that the putrefaction and fermentation of mixtures of animal and vegetable substances were accelerated by additions of absorbent earths and of Peruvian bark; he also found, that although unburnt calcareous earths were leptic, quick-lime and lime-water prevented putrefaction, but that they destroyed or dissolved the texture of flesh.

The experiments of the author of the *Essai pour servir à l'Histoire de la Putrefaction*, shew that metallic salts, resinous powders, extracts of bark, and opium, are very powerfully antiseptic, and that salts with earthy bases are less antiseptic than any other salts.

**PUTTY.** The calx of tin known by the name of putty, is generally used to polish various hard bodies, as glass, metallic specula for reflecting telescopes, &c. When fused with lead and sand it produces enamel; and serves also to cover earthen ware, giving to it a glassy and neat surface for use.

**PUZZOLANA.** This is a volcanic production of a gray, brown, yellowish, or blackish colour, loose, granular, or dusty and rough, porous and spongy, resembling a clay hardened in fire, and then reduced to a gross powder. It contains, mixed with it, various heterogeneous substances: its specific gravity is from 2, 5 to 2, 8, and it is in some degree magnetic: it scarcely effervesces with acids, though partially soluble in them: it melts easily per se: but its most distinguishing property is, that it hardens very suddenly when mixed with  $\frac{1}{3}$  of its weight of lime and water, and forms a cement, which is more durable in water than any other. According to Bergman's analysis, one hundred parts of it contain from 55 to 60 of siliceous earth, 19 or 20 of argillaceous, 5 or 6 of calcareous, and from 15 to 20 of iron. It is evidently a martial argillaceous marl that has suffered a moderate heat. Its hardening power arises from the dry state of the half-baked argillaceous particles, which makes them imbibe water very rapidly, and thus accelerates the desiccation of the calcareous part; and also from the quantity and semi-phlogisticated state of the iron contained in it. It is found not only in Italy, but also in France, in the provinces of Auvergne and Limoges, and also in England, and elsewhere.

**PYRITACEOUS LIMESTONE.** This stone is called by the French *Pierre de St. Ambroix*. It is of an iron-gray colour, interspersed with shining particles. Its texture is compact, and scarcely gives fire with steel. Its specific gravity is 2,7034.

It is soluble in acids, and mostly with effervescence: calcines in a strong fire: makes nitre slightly detonate: and if distilled, affords a small portion of vitriolic acid, and some sulphur sublimes.

Its component parts are 75 of mild calcareous earth, and 25 of pyrites, in which are contained 14 of argill, 7 of quartz and sulphur, and 4 of iron.

**PYRITES.** Certain metallic combinations, which contain a very large proportion of sulphur, are known by this name. They are not indeed entitled to any particular class distinct from ores; yet their abundance and other properties are sufficient to justify the insertion of a separate article\*.

Although sometimes pyrites contains more metal than some ores, yet generally

\* From Macquer.



it contains less metal, and a larger quantity of mineralizing substances, sulphur and arsenic, and particularly of unmetallic earth. The connexion of these matters is also much stronger in pyrites than in ores, and they are accordingly much harder; so that almost every pyrites can strike sparks from steel. From this property of striking sparks from steel they have been called pyrites, which is a Greek word signifying fire-stone. Pyrites was formerly used for fire-arms, as we now use flints; hence it was called carabine-stone. It is still named by some, marcasite. Perhaps no other kind of natural body has received so many names. Persons curious to know the other names less used than those we have mentioned, may find them in Henckel's Pyritologia. We think, with that celebrated chemist, that the subject has been perplexed by this multiplicity of names; for before his great and excellent work, the notions concerning pyrites were very confused and inaccurate.

Pyrites differs also from ores by its forms and positions in the earth. Although pyritous minerals generally precede, accompany, and follow veins of ores; they do not, properly speaking, themselves form the oblong and continued masses called veins, as ores do, but they form masses sometimes greater and sometimes smaller, but are always distinct from each other. Large quantities of them are often found unaccompanied by ores. They are formed in clays, chalk, marles, marbles, plasters, alabasters, slates, spars, quartz, granites, crystals, in a word, in all earths and stones. Many of them are also found in pit-coals, and in other bituminous matters.

Pyrites is also distinguishable from ores by its lustre and figure, which is almost always regular and uniform, externally or internally, or both. Some ores, indeed, like those of lead, many ores of silver, and some others, have regular forms, and are in some manner crystallized; but this regularity of form is not so universal, and so conspicuous in ores as in pyrites. The lustre of pyrites seems to be caused by its hardness, and the regularity of its form by the quantity of mineralizing substances which it contains.

By all these marks we may easily, and without analysis, distinguish pyrites from true ores. When we see a mineral that is heavy, possessed of metallic lustre, and of any regular form, the mass of which appears evidently to be entire, that is, not to have been a fragment of another mass, and which is so hard as to be capable of striking sparks from steel, we may be assured that such a mineral is a pyrites, and not an ore.

The class of pyrites is very numerous, various, and extensive. They differ one from another in the nature and proportions of their component parts, in their forms, and in their colours. The forms of these minerals are exceedingly various. No solid regular or irregular can easily be conceived that is not perfectly imitated by some kind of pyrites. They are spherical, oval, cylindrical, pyramidal, prismatical, cubic; they are solids with 5, 6, 7, 8, 9, 10, &c. sides. The surface of some is angular, and consists of many bases of small pyramids, while their substance is composed of these pyramids, the points of which all unite in the centre of the mass.

Pyritous minerals differ also in their component substances. Some of them are called sulphureous, martial, cupreous, arsenical, as one or other of these substances predominate. We must observe with Henckel, whose authority is very great on this subject, that in general all pyrites are martial, as ferruginous earth is the essential and fundamental part of every pyrites. This earth is united with an unmetallic earth, with sulphur or arsenic, or with both these matters; in which  
case

case the sulphur always predominates over the arsenic, as Henckel observes. He considers these as the only essential principles of pyrites, and believes that all the other matters, metallic or unmetallic, which are found in it, are only accidental; amongst which he even includes copper, although so much of it exists in some kinds of pyrites, that these are treated as ores of copper, and sometimes contain even 50lb. of copper each quintal. Many other metals, even gold and silver, are sometimes combined in pyrites; but these are less frequent, and the precious metals always in very small quantities; they are therefore justly to be considered as accidental to pyrites. The different substances composing pyrites sensibly affect its colours. Henckel distinguishes them in general into three colours, white, yellowish or a pale yellow, and yellow. He informs us, that these three colours are often so blended one with another, that they cannot be easily distinguished, unless when compared together.

The white pyrites contain most arsenic, and are similar to cobalt and other minerals abounding in arsenic. The Germans call them *mispickel*, or *mispilt*. Iron and arsenic form the greatest part of this pyrites. As arsenic has the property of whitening copper, some pyritous minerals almost white, like that of Chemnitz in Misnia, are found to contain forty pounds of copper per quintal, and which are so much whitened by the arsenic that they are very like white pyrites. But Henckel observes, that these pyritous matters are very rare, and are never so white as the true white pyrites, which is only ferruginous and arsenical.

Yellowish pyrites is chiefly composed of sulphur and iron. Very little copper and arsenic are mixed with any pyrites of this colour, and most of them contain none of these two metallic substances. This is the most common kind of pyrites: it is to be found almost everywhere. Its forms are chiefly round, spherical, oval, flattened, cylindrical; and it is composed internally of needles or radii, which unite in the centre or in the axis of the solid.

Yellow pyrites receives its colour from the copper and sulphur which enter into its composition. Its colour, however, is inclined to a green, but is sufficiently yellow to distinguish it from the other two kinds of pyrites, particularly when they are compared together. To make this comparison well, the pyrites must be broken, and the internal surfaces must be placed near each other. The reason of this precaution is, that the colour of minerals is altered by exposure to the air.

Persons accustomed to these minerals can easily distinguish them. The chief difficulty is to distinguish white pyrites from cobalt and other minerals, which also contain some copper, and much arsenic.

Hence then we see, that arsenic is the cause of whiteness in pyrites, and is contained in every pyrites of that colour; that copper is the principal cause of the yellow colour of pyrites, and that every pyrites which is evidently yellow contains copper; that sulphur and iron produce a pale yellow colour, which is also produced by copper and arsenic; hence some difficulty may arise in distinguishing pyrites from its colours. We may also observe, that sulphur and arsenic, without any other substance, form a yellow compound, as we see from the example of orpiment or yellow arsenic. Thus, although the colours of the pyrites enable us to distinguish its different kinds, and to know their nature at first sight, particularly when we have been accustomed to observe them; yet we cannot be entirely certain concerning the true nature of these minerals, and even of all minerals in general, that is, to know precisely the kinds and proportions of their component substances, but by chemical analysis and decomposition.



Besides the above-mentioned matters which compose pyrites, it also contains a considerable quantity of unmetallic earth, that is, an earth which cannot by any process be reduced to metal. Henckel, Cramer, and all those who have examined this matter, mention this earth, and prove its existence.

We ought to observe, that this earth is combined with the other principles of the pyrites, and not merely interposed between its parts. It must therefore be distinguished from other earthy and stony matters mixed accidentally with pyrites, and which do not make a part of the pyrites, since they may be separated by mechanical means, and without decomposing that mineral: but the earth of which we now treat is intimately united with the other constituent parts of the pyrites, is even a constituent part of pyrites, and essential to the existence of this mineral, and cannot be separated but by a total decomposition of it.

According to Henckel, this unmetallic earth abounds much in the white pyrites, since he found from the analysis which he made, that the iron, which is the only metal existing in these pyrites, is only about  $\frac{1}{10}$  part of the fixed substance that remains after the arsenic has been expelled by torrefaction or sublimation.

A much larger quantity of iron is in the pale yellow pyrites, according to Henckel. The proportion of iron is generally about twelve pounds to a quintal of pyrites, and sometimes fifty or sixty pounds: this is therefore called martial pyrites. It contains about  $\frac{1}{4}$  of its weight of sulphur, and the rest is unmetallic earth.

The quantity of unmetallic earth contained in the yellow or cupreous pyrites, which are also martial, since, as we have observed, iron is an essential part of every pyrites, has not yet been determined. They probably contain some of that earth, though perhaps less of it than the others.

The nature of this unmetallic earth of pyrites has not been well examined. Henckel thinks that it is an earth disposed already by nature to metallization, but not sufficiently elaborated to be considered as a metallic earth. See the articles METALS and METALLIZATION. This opinion is not improbable; but as alum may be obtained from many pyrites, may we not suspect that this unmetallic earth is of the nature of the basis of alum or argillaceous earth? See ALUM and CLAY. Perhaps also this earth is different in different kinds of pyrites. The subject deserves to be well examined.

Although pyrites is not so valuable as true ores, because in general it contains less metal, and but exceedingly little of the precious metals; and because its metallic contents are so difficult to be extracted that, excepting cupreous pyrites, which is called pyritous copper ore, it is not worked for the sake of the contained metal; yet it is applied to other purposes, and furnishes us with many useful substances; for from it we obtain all our green and blue vitriols, much sulphur, arsenic, alum, and orpiment. See the principal processes by which these substances are extracted from pyrites, under the article SMELTING OF ORES.

As every pyrites contains iron, and most of them contain also sulphur; as the pyrites most frequently found contains only these two substances with the unmetallic earth; and as iron and sulphur have a singular action upon each other, when they are well mixed together and moistened; hence many kinds of pyrites, particularly those which contain only the principles now mentioned, sustain a singular alteration, and even a total decomposition, when exposed during a certain time to the combined action of air and water. The moisture gradually penetrates them, divides, and attenuates their parts; the acid of the sulphur, particularly attacks the martial earth, and also the unmetallic earth; its unflammable principle

principle is separated from it, and is dissipated. While these alterations happen, the pyrites changes its nature. The acid of the sulphur which is decomposed forms with the fixed principles of the pyrites, vitriolic, aluminous, and selenitic salts; so that a pyrites, which was once a shining, compact, very hard mineral, becomes in a certain time a grayish, saline, powdery mass, the taste of which is saline, austere, and stiptic.

Lastly, if this mass be lixiviated with water, crystals of vitriol, and sometimes of alum, according to the nature of the pyrites employed, may be obtained by evaporation and crystallization.

This alteration and spontaneous decomposition of pyrites is called efflorescence and vitriolization; because the pyrites becomes covered with a saline powder, and because vitriol is always formed. This vitriolization is more or less quickly accomplished in pyrites according to its nature. It is a kind of fermentation excited by moisture amongst the constituent parts of these minerals; and it is so violent in those which are most disposed to it, that is, in the pale-yellow pyrites, which contain chiefly sulphur and iron, that when the quantity of these is considerable, not only a sulphureous vapour and heat may be perceived, but also the whole kindles and burns intensely. The same phenomena are observable, and the same results are formed, by mixing well together and moistening a large quantity of filings of iron and powdered sulphur; which experiment Lemerier has made, to explain the causes of subterranean fires and volcanoes.

We cannot doubt that, as the earth contains very large masses of pyrites of this kind, they must undergo the same changes when air and moisture penetrate the cavities containing them; and the best natural philosophers agree, that very probably this surprising decomposition of pyrites is the cause of subterranean fires, of volcanoes, and of mineral waters, vitriolic, aluminous, sulphureous, hot and cold.

No other pyrites is subject to this spontaneous decomposition, when exposed to humid air, but that which is both martial and sulphureous, that is the pale-yellow pyrites. The arsenical pyrites, or that which contains little or no sulphur, is not changed by exposure to air. This latter kind is harder, heavier, and more compact than the former. The pyrites which is angular and regularly shaped, is chiefly of this kind. Wallerius, in his Mineralogy, proposes to distinguish this kind of pyrites by the name of marcasite. When cut, it may be polished so well as to give a lustre almost equal to that of diamonds; but without refracting or decomposing the light; for it is perfectly opaque. It has been employed some years past in the manufacture of toys, as of buckles, necklaces, &c. and is called in commerce marcasite. See WATERS (MINERAL). ORES. SMELTING OF ORES.

**PYROMETER.** An instrument contrived for measuring the expansions and contractions of bodies by change of temperature. See EXPANSION.

**PYROMETER OF WEDGWOOD.** In this article I have abridged the papers of the inventor in the Phil. Transf. vols. lxii and lxiv.

A measure for the higher degrees of heat, such as the common thermometers afford for the lower ones, would be an important acquisition both to the philosopher and the practical artist. The latter must feel the want of such a measure on many occasions: particularly when he attempts to follow, or apply to use, the curious experiments of Mr. Pott, related in his Lithogeognosia, and other modern writers upon similar subjects. When we are told, for instance, that such and such materials were changed by fire into a fine white, yellow, green, or other coloured glass,



glass, and find that these effects do not happen, unless a particular degree of fire has fortunately been hit upon, which degree we cannot be sure of succeeding in again—when we are disappointed by having the result at some times an unvitified mass, and at others an over-vitrified scoria, from a little deficiency or excess of heat—when we see colours altered not only in shade but in kind, and in many cases destroyed by a small augmentation of the heat which had produced them—how much is it to be wished that the authors had been able to convey to us a measure of the heat made use of in their valuable processes!

Mr. Wedgwood, in a long course of experiments for the improvement of the manufacture he is engaged in, found some of his greatest difficulties to arise from not being able to ascertain the heat to which the experiment-pieces had been exposed; and having no other resource, he was obliged at first to content himself with such measures as his own kilns and the different parts of them afforded. Thus the kiln in which his glazed ware is fired furnishes three measures, the bottom being of one heat, the middle of a greater, and the top still greater; the kiln in which the biscuit ware is fired furnishes three or four others, of higher degrees of heat; and by these he marked his registered experiments. But these measures were neither fully adequate to his own views, nor capable of being communicated to others; their use is confined to a particular structure of furnaces, and mode of firing; and upon any alteration in these, they would become useless and unintelligible, even where now they are best known. And indeed as this part of the operation is performed by workmen of the lowest class, it is impossible to depend upon any great accuracy even in one and the same furnace. It has accordingly often happened, that the pieces fired in the top of the kiln in one experiment, have been made no hotter than those fired in the middle in another, and vice versa.

The force of fire, in its higher as well as lower stages, can no otherwise be justly ascertained than by its effects upon some known body. Mr. Wedgwood observed that compositions of calces of iron with clay assumed, from different degrees of fire, such a number of distinct colours and shades as promised to afford useful criteria of the respective degrees.

With this idea he prepared a quantity of such a composition, and formed it into circular pieces, about an inch in diameter, and a quarter of an inch thick. A number of these was placed in a kiln, in which the fire was gradually augmented, with as much uniformity and regularity as possible, for near sixty hours. The pieces, taken out at equal intervals of time during this successive increase of heat, and piled in their order upon one another in a glass tube, exhibited a regular and pretty extensive series of colours; from a flesh-colour to a deep brownish-red, from thence to a chocolate, and so on to nearly black, with all the intermediate tints between these colours. A rack being fixed to the tube, like the scale of a thermometer, and the number of the pieces marked upon it respectively opposite to them, it is obvious that these numbers may be considered as so many thermometric divisions or degrees; and that, if another piece of the same composition be fired in any other kiln, or furnace, not exceeding the utmost heat of the first, it will acquire a colour corresponding to some of the pieces in the tube, and thus point out the degree of heat which that piece, and consequently such other matters as were in the fire along with it, have undergone.

It must however be confessed, that, for general use, a thermometer on this principle is liable to objection, as ideas of colours are not perfectly communicable by words; nor are all eyes, or all light, equally adapted for distinguishing them, especially

especially the shades, which approach near to one another; and the effects of phlogistic vapours, in altering the colour, may not in all cases be easily guarded against.

In considering this subject attentively, another property of argillaceous bodies occurred to Mr. Wedgwood; viz. the diminution of their bulk by fire. This he found to be a more accurate and extensive measure of heat than the different shades of colour.

He found that this diminution takes place in a low red heat; and that it proceeds regularly, as the heat increases, till the clay becomes vitrified, and consequently to the utmost degree that crucibles or other vessels made of this material can support. The total contraction of some good clays which he examined in the strongest of his own fires, is considerably more than one-fourth part in every dimension.

If, therefore, we can procure at all times a clay sufficiently apyrous or unvitrescible, and always of the same quality in regard to contraction by heat; and if we can find means of measuring this contraction with ease and minute accuracy, Mr. Wedgwood thinks that we shall be furnished with a measure of fire sufficient for every purpose of experiment or business.

We have in different parts of England immense beds of clay; each of which, at equal depths, is pretty uniform in quality throughout its whole extent. Mr. Wedgwood found, that some of the purest Cornish porcelain clays seem the best adapted, both for supporting the intensity, and measuring the degrees of fire.

For preparing and applying this material to thermometric purposes, he proposes the following method.

The clay is first to be washed over, and, whilst in a dilute state, passed through a fine lawn. It must then be made dry, and put up in boxes.

While the clay is thus kept dry in boxes, as well as while it continues in its natural bed, it is secure from alterations in quality, which clays in general are subject to undergo when exposed, for a long course of years, to the joint actions of air and moisture. In the lawns, Mr. Wedgwood made use of, the interstices were each less than the 100,000th part of an inch. If Mr. Wedgwood means, as I suppose he does, that the square interstices of his lawn were each less than the 100,000th part of a square inch, the number of threads in an inch were about 320.

The dry clay is to be softened for use with about two fifths of its weight of water; and formed into small pieces, in little moulds of metal six-tenths of an inch in breadth, with the sides pretty exactly parallel, this being the dimension intended to be measured, about four-tenths of an inch deep, and one inch long. To make the clay deliver easily, it will be necessary to oil the mould, and make it warm.

These pieces, when perfectly dry, are put into another iron mould or gage, consisting only of a bottom, with two sides, five-tenths of an inch deep; to the dimensions of which sides the breadth of the pieces is to be pared down.

For measuring the diminution which they are to suffer from the action of fire, another gage is made, of two pieces of brass, twenty-four inches long, with the sides exactly straight, divided into inches and tenths, fixed five-tenths of an inch asunder at one end, and three-tenths at the other, upon a brass plate, so that one of the thermometric pieces, when pared down in the iron gage, will just fit to the wider end. Let us suppose this piece to have diminished in the fire one-fifth of

its



its bulk, it will then pass on to half the length of the gage; if diminished two-fifths, it will go on to the narrowest end; and in any intermediate degree of contraction, if the piece be slid along till it rests against the converging sides, the degree at which it stops will be the measure of its contraction, and consequently of the degree of heat it has undergone.

These are the outlines of what appeared to Mr. Wedgwood necessary for the making and using of this thermometer; and he expresses his hope that the whole process will be found sufficiently simple and easy of execution. It may nevertheless be proper to take notice of a few minuter circumstances, and to mention some observations which occurred in the progress of the inquiry.

As there ought to be a certainty of the clay being easily and at all times procurable in sufficient quantity, and on moderate terms, Mr. Wedgwood offered to the Royal Society a sufficient space in a bed of the Cornwall clay to supply the world with thermometric pieces for numerous ages.

In order to be assured that the clay made use of for these thermometers is perfectly similar, it will be best to dig it out of the earth in considerable quantity at once, an extent of some square feet or yards in area, and to the depth of six or seven yards or more from the surface, and to mix the whole thoroughly together, previous to the further preparation already mentioned.

This clay, dried by the summer heat, or in a moderately warm room, or with more heat before a fire, has not been observed to differ in degree of dryness. After being so dried, it loses about a hundredth part of its weight in the heat of boiling water, about as much more in that of melted lead, and from thence to a red heat ten parts, in all  $\frac{1}{100}$ . Each of these heats soon expels from the clay its determinate quantity of matter, chiefly air; after which, the same heat, though continued for many hours, has no further effect. Mr. Wedgwood had some hopes that the gradation of the common thermometer might be continued, upon this principle, up to the red-heat at which the shrinking of the clay commences, so as to connect the two thermometers together by one series of numbers; but the loss of weight appears not to be sufficiently uniform or proportional to the degree of heat to answer that purpose, for it was found to go on quicker, and bladders tied to the mouths of the vessels in which the pieces were heated, became more rapidly distended at the commencement of redness than at any other time. From low red-heat to a strong one, such as copper melts in, the loss of weight was only about two parts in a hundred; though the difference between these two heats appears to be much greater than what the same loss corresponds to in the lower stages. After this period, the decrease of weight entirely ceased.

The vapours expelled from the clay, caught separately in the different degrees of heat, seemed, from the few trials made with them, to consist of common air mixed with fixed air. They all precipitated lime-water, that which was first extricated exceeding weakly, the others more and more considerably; but the last not near so strongly as the air expelled from lime-stone in burning. None of them were inflammable.

The thermometric pieces may be formed much more expeditiously than in the single mould, by means of an instrument used for similar purposes by potters. It consists of a cylindrical iron vessel, with holes in the bottom, of the form and dimensions required. The soft clay put in the vessel is forced by a press down through these apertures, in long rods, which may be cut while moist, or broken when dry, into pieces of convenient lengths. It was hoped that this method would of itself have been sufficient, without the addition of the

paring gage, making proper allowance, in the size of the holes, for the shrinking of the clay in drying. But it was found that a variety of little accidents might happen to alter the shape and dimensions of the pieces, in a sensible degree, while in their soft state; so that it will be always safest to have recourse to the paring gage for ascertaining and adjusting their breadth when perfectly dry, this being the period at which the pieces are exactly alike with regard to their future diminishing; so that if they are now reduced to the same breadth, we may be sure that they will suffer equal contractions from equal degrees of heat afterwards, whether they have been made in a mould, or by a press, or in any other way; neither is any variation in the length or thickness of these pieces of the least consequence, provided one of the dimensions, that by which they are afterwards to be measured, is made accurate to the gage.

It will be proper to bake the pieces, when dry, with a low red-heat, in order to give them some firmness or hardness, that they may, if necessary, be able to bear package and carriage; but more especially to prepare them for being put into an immediate heat, along with the matters they are to serve as measures to, without bursting or flying, as unburnt clay would do. We need not be solicitous about the precise degree of heat employed in this baking, provided only that it does not exceed the lowest degree which we shall want to measure in practice; for a piece that has suffered any inferior degrees of heat, answers as well for measuring higher ones, as a piece which has never been exposed to fire at all. In this part of the preparation of the pieces, it may be proper to inform the operator of a circumstance which, though otherwise immaterial, might at first disconcert him: if the heat is not in all of them exactly equal, he will probably find that while some have begun to shrink, others are rather enlarged in their bulk; for they all swell a little just on the approach of redness. As this is the period of the most rapid produce of air, the extension may perhaps be owing to the air having at this moment become elastic to such a degree, as to force the particles of the clay a little asunder before it obtains its own enlargement.

Each division of the scale, though so large as a tenth of an inch, answers to a 600th part of the breadth of the little piece of clay. We might go to much greater nicety, either by making the divisions smaller, or the scale longer; but it is not apprehended that any thing of this kind will be found necessary: and indeed, in proceeding much farther in either way, we may possibly meet with inconveniencies sufficient to counterbalance the apparent additional accuracy of measurement.

The divisions of this scale, like those of the common thermometers, are unavoidably arbitrary; but the method here proposed appears sufficiently commodious and easy of execution, the divisions being adjusted by measures everywhere known, and at all times obtainable: for, however the inches used in different countries may differ in length, this cannot affect the accuracy of the scale, provided that the proportions between the wider and narrower end of the gage are exactly as five-tenths of those inches to three-tenths, and the length 240 of the same tenths; and that the pieces in their perfectly dry state, before firing, fit precisely to the wider end. When one gage is accurately adjusted to these proportional measures, two pieces of brass should be made, one fitting exactly into one end, and the other into the other; these will serve as standards for the ready adjustment of other gages to the dimensions of the original.

By this simple method we may be assured that thermometers on this principle, though made by different persons, and in different countries, will all be equally



affected by equal degrees of heat, and all speak the same language: the utility of this last circumstance is now too well known to need being insisted on.

If a scale two feet in length should be reckoned inconvenient, it may be divided into two, of one foot each, by having three pieces of brass fixed upon the same plate; the first and second, five-tenths of an inch apart at one end, and four-tenths at the other; the second and third, four-tenths at one end, and three-tenths at the other; so that the first reaches to the 120th division, and the second from thence to the 240th.

As this thermometer, like all others, can express only the heat felt by itself, the operator must be careful to expose the pieces to an equal action of the fire with the body whose heat he wants to measure by them. In kilns, ovens, reverberatories, under a muffle, and wherever the heat is pretty steady and uniform, the means of doing this are too obvious to need being mentioned. But in a naked fire, where the heat is necessarily more fluctuating, and unequal in different parts of the fuel, some precaution will be required.

The thermometer-piece may generally be put into the crucible, along with the subject matter of the experiment. But where the matter is of such a kind as to melt and stick to it, the piece may be previously inclosed in a little case made of crucible clay. The smallness of the pieces will admit of this being done without inconvenience, at least in any but the smallest crucibles, as the pieces themselves may be diminished to any size that may be found proper, provided only that one of the dimensions, five-tenths of an inch, be preserved in the manner before mentioned.

For the very smallest sort of crucibles, the case may be put in close to the crucible, so as to form as it were an addition to its bulk on the outside. If it be asked, why the case is not always thus put in by the side of the crucible? it is answered, that in judging of the heat of large crucibles from a thermometer-piece placed on the outside of them, we may sometimes be deceived, as the piece in its little case has been found to heat sooner than the matter in the larger vessel; but in small ones, as the crucible and case are nearly alike in bulk, there is little danger of error from this cause.

These thermometer-pieces possess some singular properties, which we could not have expected to find united in any substance whatever, and which peculiarly fit them for the purposes they are here applied to.

1. When baked by only moderate degrees of fire, though they are, like other clays, of a porous texture, and imbibe water; yet, when saturated with the water, their bulk continues exactly the same as in a dry state.
2. By very strong fire, they are changed to a porcelain or semi-vitreous texture; nevertheless, their contraction, on further augmentations of the heat, proceeds regularly, as before, up to the highest degree of fire that Mr. Wedgwood has been able to produce.
3. They bear sudden alternatives of heat and cold; may be dropped at once into intense fire; and, when they have received its heat, may be plunged as suddenly into cold water, without the least injury from either.
4. Even while saturated with water in their porous state, they may be thrown immediately into a white heat, without bursting or suffering any injury.
5. Sudden cooling, which alters both the bulk and texture of most bodies, does not at all affect these, at least not in any quality subservient to their thermometric uses.
6. Nor are they affected by long continuance in, but solely by, the degree of

of heat they are exposed to. In three minutes, or less, they are perfectly penetrated by the heat which acts upon them, so as to receive the full contraction which that degree of heat is capable of producing, equally with those which had undergone its action during a gradual increase of its force for many hours. Strong degrees of heat are communicated to them with more celerity than weak ones; perhaps the heat may be more readily transmitted, in proportion as the texture becomes more compact.

These facts have been ascertained by many experiments, the particulars of which are omitted, because they would swell this article much beyond the bulk intended.

The use and accuracy of this thermometer for measuring, after an operation, the degree of heat which the matter has undergone, will be apparent. The foregoing properties afford means of measuring it also easily and expeditiously, during the operation, so that we may know when the fire is increased to any degree previously determined upon. The piece may be taken out of the fire in any period of the process, and dropped immediately into water, so as to be fit for measuring by the gage in a few seconds of time. At the same instant, another piece may be introduced into the place of the former, to be taken out and measured in its turn; and thus alternately, till the desired degree of heat is obtained. But as the cold piece will be two or three minutes in receiving the full heat, and corresponding contraction; to avoid this loss of time, it may be proper on some occasions to have two or more pieces, according to convenience, put in together at first, that they may be successively cooled in water, and the degrees of heat examined at shorter intervals. It will be unnecessary to say any thing further upon precautions or procedures which the very idea of a thermometer must suggest, and every experimenter will readily find means to obviate.

It only now remains, that the language of this new thermometer be understood, and that it may be known what the heats meant by its degrees really are. For this purpose a great number of experiments have been made, from which the following results are selected.

The scale commences at a red-heat, fully visible in day-light; and the greatest heat that Mr. Wedgwood obtained in his experiments is  $160^{\circ}$ . This degree he produced in an air furnace about eight inches square.

Mr. Alchorne tried the necessary experiments with the pure metals at the Tower, to ascertain at what degrees of this thermometer they go into fusion; and it appears that Swedish copper melts at 27, silver at 28, and gold at 32.

Brass is in fusion at 21. Nevertheless, in the brass and copper foundries, the workmen carry their fires to  $140^{\circ}$  and upwards; but for what purpose they so far exceed the melting heat, or whether so great an additional melting heat be really necessary, Mr. Wedgwood says he has not learned.

The welding heat of iron is from 90 to 95; and the greatest heat that could be produced in a common smith's forge 125.

Cast-iron was found to melt at  $130^{\circ}$ , both in a crucible in Mr. Wedgwood's furnace, and at the foundry; but could not be brought into fusion in the smith's forge, though that heat is only  $5^{\circ}$  lower. The heat by which iron is run down among the fuel for casting is  $150^{\circ}$ .

As the welding state of iron is a softening or beginning fusion of the surface, it has been generally thought that cast-iron would melt with much less heat than what is necessary for producing this effect upon the forged; whereas, on the con-



trary, cast-iron appears to require, for its fusion, a heat exceeding the welding heat 35 or 40°, which is much more than the heat of melted copper exceeds the lowest visible redness.

Thus we find, that though the heat for melting copper is by some called a white heat, it is only 27° of this thermometer. The welding heat of iron, or 90°, is likewise a white heat; even 130°, at which cast-iron is in fusion, is no more than a white heat; and so on to 160° and upwards is all a white heat still. This shews abundantly how vague such a denomination must be, and how inadequate to the purpose of giving us any clear ideas of the extent of what we have been accustomed to consider as one of the three divisions of heat in ignited bodies.

A Hessian crucible, in the iron foundry, viz. about 150° melted into a slag-like substance. Soft iron nails, in a Hessian crucible in Mr. Wedgwood's furnace, melted into one mass with the bottom of the crucible, at 154°: the part of the crucible above the iron was little injured.

The fusing heat of the glass furnaces Mr. Wedgwood examined, or that by which the perfect vitrification of the materials is produced, was at one of them 114° for flint-glass, and 124° for plate-glass; at another it was only 70° for the former, which shews the inequality of heat, perhaps unknown to the workmen themselves, made use of for the same purpose. After complete vitrification, the heat is abated for some hours to 28 or 29°, which is called the settling heat; and this heat is sufficient for keeping the glass in fusion. The fire is afterwards increased, for working the glass, to what is called the working heat; and this Mr. Wedgwood found, in plate-glass, to be 57°.

Delft-ware is fired by a heat of 40 or 41°; cream-coloured or queen's-ware, by 86°; and stone-ware, called by the French pots de grès, by 102°; by this strong heat, it is changed to a true porcelain texture. The thermometer-pieces begin to acquire a porcelain texture about 110°.

The above degrees of heat were ascertained by thermometer-pieces fired along with the ware in the respective kilns. But this thermometer affords means of doing much more, and going further in these measures than could at first have been expected; it will enable us to ascertain the heats by which many of the porcelains and earthen wares of distant nations and different ages have been fired: for as burnt clay, and compositions in which clay is a prevailing ingredient, suffer no diminution of their bulk by being repassed through degrees of heat which they have already undergone, but are diminished by any additional heat, as has been before observed, if a fragment of them be made to fit into any part of the gage, and then fired along with a thermometer-piece till it begins to diminish, the degree at which this happens, points out the heat by which it had been fired before. Of several pieces of ancient Roman and Etruscan wares, which Mr. Wedgwood examined, none appeared to have undergone a greater heat than 32°, and none less than 20°; for they all began to diminish at those or the intermediate degrees.

By means of this thermometer, some interesting properties of natural bodies may likewise be discovered or more accurately determined, and the genus of the bodies ascertained. Jasper, for instance, is found to diminish in the fire, like an artificial mixture of clay and siliceous matter; granite, on the contrary, has its bulk enlarged by fire, whilst flint and quartzose-stones are neither enlarged nor diminished. These experiments were made in fires between 70 and 80° of this thermometer. A sufficient number of facts like these, compared with each other,

other, and with the properties of such natural or artificial bodies as we wish to find out the composition of, may lead to various discoveries, of which Mr. Wedgwood says he has already found some promising appearances; but that many more experiments are wanting to enable him to speak with that certainty and precision on these subjects which they appear to deserve.

A piece of an Etruscan vase melted completely at  $33^{\circ}$ ; pieces of some other vases and Roman ware about  $36^{\circ}$ ; Worcester china vitrified at  $94^{\circ}$ ; Mr. Sprimont's Chelsea china at  $105^{\circ}$ ; the Derby at  $112^{\circ}$ ; and Bow at  $121^{\circ}$ ; but Bristol china shewed no appearance of vitrification at  $135^{\circ}$ . The common sort of Chinese porcelain does not perfectly vitrify by any fire Mr. Wedgwood could produce; but began to soften about  $120^{\circ}$ , and at  $156^{\circ}$  became so soft as to sink down, and apply itself close upon a very irregular surface underneath. The true stone nankeen, by this strong heat, does not soften in the least; nor does it even acquire a porcelain texture, the unglazed parts continuing in such a state as to imbibe water and stick to the tongue. The Dresden porcelain is more refractory than the common Chinese, but not equally so with the stone nankeen. The cream-coloured or queen's ware bears the same heat as the Dresden, and the body is as little affected by this intense degree of fire.

Mr. Pott says, that to melt a mixture of chalk and clay in certain proportions, which proportions appear from his tables to be equal parts, is among the master-pieces of art. This mixture melts into a perfect glass at  $123^{\circ}$  of this thermometer.

The whole of Mr. Pott's or any other experiments may, by repeating and accompanying them with these thermometric pieces, have their respective degrees of heat ascertained, and thereby be rendered more intelligible and useful to the reader, the experimenter, and the working artist.

Mr. Wedgwood found from the analysis of the clay of which the thermometric pieces are formed, that it consists of two parts of pure siliceous earth to three parts of pure argillaceous or aluminous earth.

Mr. Wedgwood afterwards endeavoured to connect his thermometer with that of Fahrenheit's, by means of a silver expansion-piece as an intermediate measure. In order to procure a gage for this purpose like that by which the thermometer-pieces are measured, he made choice of tobacco-pipe clay, mixed with charcoal in fine powder, in the proportion of three parts of the charcoal to five of the clay by weight. By a free access of air, in the burning by which the gage is prepared for use, the charcoal is consumed, and leaves the clay extremely light and porous; from which circumstance it bears sudden alterations of cold and heat, often requisite in these operations, much better than the clay alone.

A clear idea may be obtained of this species of gage, by conceiving two rulers or flat pieces a quarter of an inch thick fixed flat upon a smooth flat plate, a little further asunder at one end than at the other; so that they may include between them a long converging canal, in which a piece of metal is so adjusted as to fit exactly at the wider end of the canal, which is divided on one side into a number of small equal parts, and which may be considered as performing the offices both of the tube and scale of the common thermometer. When a piece of metal is heated to an exact equality with the gage, the excess of the expansion of one above the other can be measured, which is sufficient for purposes where only an uniform and graduated effect of fire is required.

In



In order to obtain a corresponding interval between Fahrenheit's thermometer and this intermediate scale, the silver-piece and gage were laid together for some time in spring water, of the temperature of  $50^{\circ}$  of Fahrenheit: the point which the piece went to in this cold state was marked (o) near the narrow end of the gage.

The heat of boiling water was taken without difficulty, by keeping the apparatus in boiling water itself during a sufficient space of time for the full heat to be communicated to it. The expansion of the silver by this heat, that is, by an increase of the heat from  $50^{\circ}$  to  $212^{\circ}$ , or a period containing  $162^{\circ}$  of Fahrenheit, was just  $8^{\circ}$  of the gage or intermediate thermometer; whence one of these degrees, according to this experiment, contains just  $20\frac{1}{4}^{\circ}$  of Fahrenheit.

For the boiling heat of mercury, it was necessary to proceed in a different manner; not to convey the heat from the mercury to the instrument, but to convey it equally to them both from another body. Mr. Wedgwood, therefore, made a small vessel for holding the mercury in the gage itself. The plate which forms the bottom of the canal, serves also for the bottom of the vessel, which is situated close to the side of the canal, and as near as possible to that part of it in which both the silver-piece, and the divisions required for this particular experiment, are contained.

The gage, with some mercury in the vessel, was laid upon a smooth and level bed of sand, on the bottom of an iron muffle kept open at one end; the fire increased very gradually till the mercury boiled, and then continued steady, so as just to keep it boiling for a considerable time. The boiling heat of mercury was thus found to be  $27\frac{1}{2}^{\circ}$  of the intermediate thermometer, which answering to an interval of  $550^{\circ}$  of Fahrenheit, makes one degree of this equal to just  $20^{\circ}$  of his.

The next object to be ascertained was an interval of correspondence between this intermediate gage and the thermometer for strong fire.

In these experiments Mr. Wedgwood found it was impossible to obtain in common fires, or in common furnaces, an uniform heat through the extent even of a few inches. He, therefore, had recourse to the fire of an enamelling oven, which was of such a magnitude as to exceed perhaps some hundreds of times the bulk of the matters required to be heated. A muffle being placed in this furnace, the gage was fixed in it as before with the silver-piece. Some of the clay thermometer-pieces were set on end upon the silver-piece, with that end of each downwards which is marked to go foremost in measuring it; that is, they were in contact with the silver in that part of their surface by which their measure is afterwards ascertained.

The fire about the oven was slowly increased for some hours, and kept as even and steady as possible. Upon opening a small door, which had been made for introducing the apparatus, and looking in from time to time, it was observed that the muffle, with the adjacent parts of the oven and ware, acquired a visible redness at the same time; and in the progress of the operation, the eye could not distinguish the least dissimilarity in the aspect of the different parts; whereas in small fires, the difference not only between the two ends of the muffle, but in much less distances, is such as to strike the eye at once.

When the muffle appeared of a low red-heat, such as was judged to come fully within the province of his thermometer, it was drawn forward towards the door of the oven; and its own door being then nimbly opened by an assistant, Mr. Wedgwood pushed the silver-piece as far as it would go. But as the division  
which

which it went to could not be distinguished in that ignited state, the muffle was lifted out, by means of an iron rod passed through two rings made for that purpose, with care to keep it steady, and avoid any shake that might endanger the displacing of the silver-piece.

When the muffle was grown sufficiently cold to be examined, he noted the degree of expansion which the silver-piece stood at, and the degree of heat shewn by the thermometer-pieces measured in their own gage; then returned the whole into the oven as before, and repeated the operation with a stronger heat, to obtain another point of correspondence on the two scales.

The first was at  $2^{\circ}\frac{1}{4}$  of his thermometer, which coincided with  $66^{\circ}$  of the intermediate one; and as each of these last has been before found to contain 20 of Fahrenheit's, the 66 will contain 1320; to which add 50, the degree of his scale to which the (o) of the intermediate thermometer was adjusted, and the sum 1370 will be the degree of Fahrenheit's corresponding to his  $2^{\circ}\frac{1}{4}$ .

The second point of coincidence was at  $6\frac{1}{4}^{\circ}$  of his, and  $92^{\circ}$  of the intermediate; which 92 being, according to the above proportion, equivalent to 1840 of Fahrenheit, add 50 as before to this number, and his  $6\frac{1}{4}^{\circ}$  is found to fall upon the 1890th degree of Fahrenheit.

It appears from hence, that an interval of four degrees upon Mr. Wedgwood's thermometer is equivalent to an interval of  $520^{\circ}$  upon that of Fahrenheit; and consequently one of the former to  $130^{\circ}$  of the latter; and that the (o) of Mr. Wedgwood corresponds to  $1077\frac{1}{3}$  of Fahrenheit.

From these data it is easy to reduce either scale to the other through their whole range; and from such reduction it will appear, that an interval of near  $480^{\circ}$  remains between them, which the intermediate thermometer serves as a measure for; that Mr. Wedgwood's includes an extent of about 32000 of Fahrenheit's degrees, or about 54 times as much as that between the freezing and boiling points of mercury, by which mercurial ones are naturally limited; that if the scale of Mr. Wedgwood's thermometer be produced downwards, in the same manner as Fahrenheit's has been supposed to be produced upwards, for an ideal standard, the freezing point of water would fall nearly on  $8^{\circ}$  below (o) of Mr. Wedgwood's, and the freezing point of mercury a little below  $80^{\circ}\frac{1}{2}$ ; and that, therefore, of the extent of now measurable heat, there are about  $\frac{1}{16}$ ths of a degree of his scale from the freezing of mercury to the freezing of water;  $18^{\circ}$  from the freezing of water to full ignition; and  $160^{\circ}$  above this to the highest degree he has hitherto attained.

Mr. Wedgwood concludes his account with the following Table of the effects of heat on different substances, according to Fahrenheit's thermometer, and his own.

	Fahr.	Wedg.
Extremity of the scale of his thermometer	32277°	240°
Greatest heat of his small air furnace	21877	160
Cast-iron melts	17977	130
Greatest heat of a common smith's forge	17327	125
Welding heat of iron, greatest	13427	95
, least	12777	90
Fine gold melts	5237	34
Fine silver melts	4717	28
Swedish copper melts	4587	27
Brass melts	3807	21



	Fabr.	Wedg.
Heat by which his enamel colours are burnt on	1857	6
Red-heat fully visible in day-light	1077	0
Red-heat fully visible in the dark	947	1
Mercury boils	600	$3\frac{673}{1000}$
Water boils	212	$6\frac{518}{1000}$
Vital heat	97	$7\frac{542}{1000}$
Water freezes	32	$8\frac{42}{1000}$
Proof spirit freezes	0	$8\frac{289}{1000}$
The point at which mercury congeals, consequently the limit of mercurial thermometers, about	40	$8\frac{596}{1000}$

In a scale of HEAT drawn up in this manner, the comparative extents of the different departments of this grand and universal agent are rendered conspicuous at a single glance of the eye. We see at once, for instance, how small a portion of it is concerned in animal and vegetable life, and in the ordinary operations of nature. From freezing to vital heat is barely a five-hundredth part of the scale; a quantity so inconsiderable, relatively to the whole, that in the higher stages of ignition, ten times as much might be added or taken away, without the least difference being discernible in any of the appearances from which the intensity of fire has hitherto been judged of. From hence at the same time we may be convinced of the utility and importance of a physical measure for these higher degrees of heat, and the utter insufficiency of the common means of discriminating and estimating their force. Mr. Wedgwood adds, that he has often found differences, astonishing when considered as a part of this scale, in the heats of his own kilns and ovens, without being perceivable by the workmen at the time, or till the ware was taken out of the kiln.

**PYROPHORUS.** By this name is denoted an artificial product, which takes fire or becomes ignited on exposure to the air. Hence, in the German language, it has obtained the name of *luft-zunder*, or air-tinder. It is prepared from alum by calcination, with the addition of various phlogistic substances. Homberg was the first that obtained it, which he did accidentally in the year 1680, from a mixture of human excrement and alum, upon which he was operating by fire. This chemist, upon the strength of some information communicated to him, was endeavouring to extract by distillation from human excrement an oil that should transmute mercury into silver; in this attempt, however, he was disappointed, as might naturally be expected. Lemerier the younger, afterwards, in the year 1713, shewed that it could not only be prepared from this substance, but also (on being previously mixed with alum) from various other bodies, that are capable of being charred. After this, M. de Savigny made it appear, that by the addition of any inflammable body whatever, a phosphorus may be made of all such substances as contain vitriolic acid combined either with earth, or with alkaline salt, or with a metallic substance. Notwithstanding this, the preference is given to alum, because its earth best retains the vitriolic acid in the fire, and hence the operation succeeds best with this salt\*.

The preparation is managed in the following manner: Three parts of alum

\* In this article, I follow Wiegand, and the copious and excellent notes of Dr. Hopson, and his anonymous friend upon the chapter on Pyrophori.

are mixed with from two to three parts of honey, or sugar; and this mixture is dried over the fire in a glazed bowl, or an iron pan, diligently stirring it all the while with an iron spatula. At first this mixture melts, but by degrees it becomes thicker, swells up, and at last runs into small dry lumps. These are triturated to powder, and once more roasted over the fire, till there is not the least moisture remaining in them, and the operator is well assured that it can liquify no more: the mass now looks like a blackish powder of charcoal. For the sake of avoiding the previous above-mentioned operation, from four to five parts of burned alum may be mixed directly with two of charcoal powdered. This powder is poured into a phial or matras, with a neck about six inches long. The phial, which however must be filled three-quarters full only, is then put into a crucible, the bottom of which is covered with sand, and so much sand is put round the former that the upper part of its body also is covered with it to the height of an inch; upon this the crucible, with the phial, is put into the furnace, and surrounded with red-hot coals. The fire being now gradually increased till the phial becomes red-hot, is kept up for the space of about a quarter of an hour, or till a black smoke ceases to issue from the mouth of the phial, and instead of this, a sulphureous vapour exhales, which commonly takes fire. The fire is kept up till the sulphureous flame is no longer to be seen; upon this the calcination must be put an end to, and the phial closed for a short time with a stopper of clay or loam. But as soon as the vessel is become so cool as to be capable of being held in the hand, the phial is taken out of the sand, and the powder contained in it transferred as fast as possible from the phial into a dry and stout glass made warm, which must be secured with a glass stopper.

For the production of this pyrophorus, it is necessary, according to Wiegleb, that there should be in its composition a newly generated sulphur, an inflammable coal, concentrated matter of fire, and calcined earth of alum, or some other fixed body, with which the newly generated sulphur may unite. Scheele concludes from his experiments, that fixed alkali is requisite for the production of pyrophorus, and mentions the following as proofs of it: that from a mixture of liver of sulphur with calcined alum, and a little powdered charcoal, he obtained, after calcination, a good pyrophorus. The same effect took place when he had mixed together and calcined a spoonful of finely triturated vitriolated tartar, with three spoonfuls of charcoal reduced to a fine powder; both these experiments Wiegleb found to be just as the author had related them; but nevertheless he does not conceive the necessity of fixed alkali, because there are also pyrophori which do not contain any fixed alkali at all. Probably the alkali serves only to retain and fix the sulphur in the same manner as the earth of alum does, and perhaps does this better, and therefore may be used in its place; to which purpose also several other substances seem to be adapted.

The opinions of philosophers relative to this phenomenon are likewise different. Some chemists have pretended, with Savigny, that there is to be found in the pyrophorus a highly concentrated vitriolic acid, which greedily attracts the moisture of the air, and is by this means so intensely heated, that the sulphur, together with the coaly substance, is inflamed by it. To this opinion however Wiegleb objects, because there is no acid in the pyrophorus perceptible to the senses; on the contrary, this substance has manifestly the taste of liver of sulphur, and dissolves, like liver of sulphur, without affording any other smell than that which accompanies every solution of hepar sulphuris. For if an uncombined acid were contained in it, that peculiar volatile and suffocating sulphureous vapour must



must inevitably be perceived, which is always produced upon the admixture of an acid with a solution of liver of sulphur. And he demands, in what part of it should this uncombined acid be contained? The quantity of acid that quits the earth of alum will either be converted into sulphur, or must fly off from the mass in consequence of the heat employed in the preparation. If it be said that it remains united with the earth of alum, in this case it would not be a disengaged acid; and its property of rapidly attracting water, and consequent incalcescence, which have been adduced as the causes of this phenomenon, are annihilated. This case is also impossible upon the whole; as an aluminous compound and liver of sulphur cannot be placed in contact with each other without the former decomposing the latter, and accordingly the solution of pyrophorus is precipitated by a solution of alum, with a disagreeable odour. There must therefore necessarily be another reason for the inflammation of this compound.

Scheele\* exposed pyrophorus to moist phlogisticated air, without observing any ignition to ensue. Mr. Bewley† found that, notwithstanding that by a repeated calcination of vitriolated tartar and charcoal much of the vitriolic acid was lost, yet a pyrophorus might be obtained, with a fresh addition of powdered charcoal, and even with the addition of an alkaline substance that exceeded the whole of the acid in quantity. Mr. Bewley obtained a pyrophorus likewise from calcined vitriol, from aluminous earth as free as possible from vitriolic acid, and from crocus martis, by the calcination of these substances with powdered charcoal and vegetable alkali. He even made a good pyrophorus without any vitriolic acid, to which he gave the name of alkaline pyrophorus, in consequence of his having obtained it by the calcination of the coal of blood with vegetable alkali, the colouring substance of which had been already extracted for the precipitation of the Prussian blue; whether the alkali employed was common alkali, or purified salt of tartar, or fixed nitre, the result was always the same: and it appears from other kinds of pyrophorus which do not contain any alum, that there are other substances besides that yield pyrophori, without containing the least particle of vitriolic acid.

The necessity for the presence of moisture, as well as of pure air, for the accension of pyrophori, appears evident from Scheele's experiments. This great observer, having made the air in a matras thoroughly dry with quick-lime, and two days afterwards put some pyrophorus in it, could not perceive that it even grew warm. On the other hand, when he put a wet sponge into the matras, and carefully closed the latter, the pyrophorus kindled in the space of a few minutes. The pyrophorus, however, would not by any means take fire in phlogisticated air. On the other hand, Mr. Bewley's experiment, according to which the pyrophorus kindled on dry paper, or dry lint, and so near the fire that some dry caustic alkali placed in the same situation did not get any moisture from the air (and likewise on a hot iron plate), seem to shew that the pyrophorus will kindle without attracting any moisture from the air: but here it may be sufficient to observe in general, that the motion of the heat, which is excited in the luminous pyrophorus, is the cause of the accension of this substance; and this motion of the heat may either arise, as in the experiments above-mentioned, from heat applied *ab extra*, or (as is the case when exposed to the common temperature of

\* See Scheele's Chemical Observations and Experiments on Air and Fire, translated by Dr. Forster, sec. 81. p. 128.

† In Priestley's Experiments and Observations on Air, vol. iii.

the atmosphere) by attracting the moisture of this latter. Mr. Bewley thinks that pyrophori have the power of decomposing the atmospheric air, and of attracting the nitrous air from it, and by this means of exciting such a heat that the inflammable particles of the pyrophorus are capable of being kindled by it. He founds his opinion upon various experiments of Dr. Priestley, who, with nitrous acid, obtained from several substances very pure vital air; as likewise on having been able to set fire, by means of nitrous acid, a pyrophorus that had not been sufficiently calcined. All pyrophori are, according to this theory, nothing but perfectly dry alkalis combined with phlogistic matter, which, in consequence of the attraction of the air, emit this phlogistic matter, when this last immediately seizes the nitrous acid existing in the air, and forms a nitrous sulphur, that is very easily decomposed, and is kindled in consequence of the heat produced by the combination.

Scheele gives the following explication of the accension of pyrophori. The liver of sulphur, of which, together with charcoal, this preparation consists, attracts the phlogiston that has been extracted from the charcoal during the calcination. This substance, which is composed of alkali, phlogiston and sulphur, will not take fire without moisture and dephlogisticated air. The alkali, which attracts the moisture strongly, is rendered incapable by it of retaining the phlogiston any longer, especially as empyreal or dephlogisticated air is present, a substance which attracts the phlogiston more powerfully. Now, in consequence of the empyreal air combining with the loosely adhering phlogiston, a quantity of heat is generated, which, together with the fresh accession of empyreal air, kindles the sulphur and charcoal, and afterwards calcines them.

M. Pilatre de Rozier asserts, that a certain quantity of phosphorus exists in the pyrophorus, and is the cause of its inflammation: for he supposed the acid of all mucilaginous substances to be the phosphoric acid. This philosopher obtained from fifty-four grains of flowers of sulphur, thirty-six grains of charcoal made of willow, and three grains of phosphorus, a kind of pyrophorus which took fire in consequence of being breathed upon, and which, on the addition of twenty-four grains of alkali, emitted a sulphureous smell, similar to that of the aluminous pyrophorus.

Instead of entering into tedious disquisitions for the purpose of examining and confuting these several opinions, Dr. Hopson's friend adduces that of M. Leonhardi, which appears to him to be the most satisfactory of any hitherto offered to the public. "As (says this author), besides the aluminous, there are other kinds of pyrophori, in which neither phosphorus nor sulphur, nor liver of sulphur, can be supposed to exist, we must seek for such an explanation as shall be equally adapted to them all. And this appears to me to be found in the inflammable air which is kindled by the heat in consequence of the accession of the respirable air to it." This theory he attempts to establish by the following arguments: "A quantity of inflammable air is actually produced in the preparation of the aluminous pyrophorus from burned alum, and a charred vegetable or animal substance.

I. "For if this mixture be calcined in Bewley's method, viz. covered up with sand in a tobacco-pipe, a sort of effervescent motion may be observed in the sand, which seems to arise from some kind of air that is extricated from it.

II. "If the pyrophorus be prepared, as it usually is, in an open phial, into which consequently the external air can enter, a flame is produced, which is nothing but an inflammable air, generated by the vitriolic acid that is detached



from the alum, and, on occasion of the mass being heated, acts upon the coal, and (on the accession of the external air) is kindled by the heat subsisting near the mouth of the phial. This flame is likewise the mark of the operation being nearly finished. If the pyrophorus be calcined till it yields no flame at all, it will never be good, because all the inflammable air is expelled. If the calcination be discontinued before the flame becomes weak, it will be but an imperfect pyrophorus; because the alkali contained in it is not dry enough to attract the moisture in the air, so as to generate a sufficient degree of heat. If, on the other hand, the process be discontinued at the time that the flame begins to get weaker, a part of the inflammable air remains in the phial upon the coaly powder, and is absorbed by it, if the evaporation of it be prevented as usual. For it is proved by the Abbé Fontana's experiments, that coals absorb all kinds of air, and consequently inflammable air. But this inflammable air being but very loosely combined, a very low degree of heat will be able to kindle, not only the inflammable air itself, but likewise, by means of it, the coal and sulphur of the pyrophorus; whether the heat, as in Bewley's experiments, be occasioned ab extra, by actual fire placed at some distance, or, as Bewley likewise experienced, by pouring upon the pyrophorus a drop of the concentrated nitrous acid (which according to Scheele's experiments cannot decompose the inflammable air), or, lastly (as takes place on the exposure of it to the air), in consequence of the moisture of this latter being attracted by the alkali."

The inflammable air contained in the aluminous pyrophorus seems to be of the nature of hepatic air, as an odour similar to that of this air is observed to arise during the burning of the pyrophorus. The pyrophorus, when kept in a loose, careless manner, loses the property of kindling in the air, because the moisture which it has slowly and gradually attracted from the air prevents its incalcescence in the air, and perhaps because the inflammable air in part evaporates. But a repeated calcination will restore to it this property; because it renders the alkali extremely dry, and makes it able to generate heat again by attracting the moisture of the air, and probably also there is a fresh extrication of inflammable air.

The same explication will hold good with respect to every kind of pyrophorus made of charcoal, alkali, and calcined vitriols, or vitriolic neutral salts, and even to Mr. Bewley's pyrophorus, which consists of alkali and charcoal. This is confirmed by an experiment of Scheele, in which, by distilling caustic alkali and charcoal together, a quantity of inflammable air was obtained, free from fixed air.

Besides this, other compositions, which, in like manner, take fire on exposure to the open air, have been by degrees made known to us: 1. The scoria of the martial regulus of antimony, as well crude as also after being dissolved, have been observed to take fire spontaneously, when laid upon a hot stone, or in the sun. Of the truth of the latter case, Wiegand says he is assured by his own experience. 2. Some assert that they have observed an inflammation ensue from honey and flour calcined according to the rules laid down above. 3. According to Geoffroy, a calcined mass of three parts of black soap, and one of diaphoretic antimony has been known to take fire spontaneously. 4. Meuser has observed, that a pyrophorus is obtained when equal parts of orpiment and iron filings are sublimed together, and ten parts of this sublimate are triturated in a mortar along with twelve of nitre of silver. 5. A pyrophorus is produced, according to Penzky, when two drachms of white sand, three of common salt, one of sulphur, two of oil of vitriol, and half an ounce of spirit of salt, are mixed together and distilled

distilled in a glass retort. In this operation a sublimate is said to be obtained, which bursts out in flames, as soon as it comes into contact with the air. 6. The spontaneous precipitate of ostiocola, from a solution of it in vitriolic acid, after having been separated by means of a filter, and dried, took fire in a warm place. 7. Pott observed the same phenomenon in the earth of the residuum after the distillation of urine, that had been putrid for a considerable time. 8. To these may also be referred a mass composed of equal parts of sulphur and iron filings; which, when thoroughly moistened with water, after some time grows hot, swells, and at last breaks out into vapour, smoke, and flame. It is difficult to ascertain the cause of these and several other similar experiments, because the circumstances attending them are complicated, and perhaps not minutely enough related. We learn however by this, that other fixed bodies besides may have the same effect, as, in the usual mode of preparing pyrophorus, appears to be produced by the earth of alum.

Those pyrophori that require a heat greater than that of the usual temperature of the atmosphere for their accension, may be termed imperfect pyrophori. They may be compared to the imperfect phosphori, and are in fact intermediate substances between the true pyrophori and ordinary combustible bodies. Most of the following taken by Dr. Hopson from Mr. Bucholz's paper, in vol. i. of the Chemical Annals, are of a different nature, and appear to be the result of fermentation, or the decomposition of water.

With a view to the prevention of fires, in many instances it may be useful to make mention, in this place, of certain substances which, when made warm to a certain degree, or merely mixed with oils, take fire and are destroyed. On occasion of a frigate that in 1781 took fire in the port of Cronstadt, just as she was preparing to set sail, though no fire had been made in her for five days before, M. Georgi, of the Imperial Academy of Petersburg, made a great number of experiments, from which we shall select the most remarkable. He impregnated gradually three pounds of Russian lamp-black with five pounds of boiled hemp-seed oil, and, after having left the mixture exposed to the air for about five hours, wrapped it up in a coarse linen cloth. This mass, after having lain in a chest for about sixteen hours, yielded a very offensive and seemingly putrid smell, not much unlike that of boiling oil. Some parts of the mass grew warm, then hot, and emitted a considerable quantity of vapour. These vapours were watery, and by no means inflammable. Within about eighteen hours after the packet was made, some part of it growing warm exhibited smoke, and immediately afterwards was actually ignited. The same happened at two or three other places; but others were scarcely warm. The fire spread very slowly, and emitted a thick stinking smoke. M. Georgi then taking the mass out of the chest, and laying it on a stone floor, where it was more exposed to the air, a flame about six inches high arose with much smoke: whenever any openings or crevices were made in the mass, they threw out vapours, which soon after took fire. The mass being thrown upon the floor, broke in pieces, and a brisk flame arose on a sudden about three feet in height, which soon ceased, when the materials continued to glimmer, at first with smoke, and afterwards without, for the space of six hours. The whole was consumed in about eight hours. The ashes, which were gray, weighed, when cold, five ounces and a half.

In another experiment, exactly similar to this as to what relates to the mixture and quantity of the materials, the inflammation did not take place for forty-one hours after the oil had been imbibed by the lamp-black. In general



the inflammation took place much sooner in fine clear days than in rainy weather.

In another experiment he impregnated three pounds of Russian lamp-black with three pounds of hemp-seed oil unboiled, and the inflammation took place in the space of nine hours. Twelve ounces of fine German lamp-black mixed with twenty-four ounces of boiled hemp-seed oil, did not grow warm till after seventy hours were elapsed; it then became gradually hotter, and emitted vapours which were not inflammable. The re-action of the materials lasted about thirty-six hours, in which time the heat was sometimes greater and sometimes less, till at last it ceased entirely. He made a great many more experiments for the Board of Admiralty at Petersburg; of which the results are these. The inflammation takes place much sooner when Russian lamp-black, which is coarse, greasy, and heavy, is impregnated with the oil, than when the German lamp-black, which is light and fine, or common wood foot, is employed for this purpose. With regard to the oils, the inflammation only happens with drying oils, either boiled or crude. The proportion of the lamp-black to the oil differed greatly in these experiments; the lamp-black or foot took fire with  $\frac{1}{10} : \frac{1}{3} : \frac{1}{2}$  equal parts, and even with twice the quantity of the oil. In general the inflammation depended more upon the mode of mixing the ingredients than upon the quantity of them; and also, as M. Georgi often observed, upon the weather; for in wet weather, the mass, after growing warm, became cold again. A packet of hemp, of about thirty pounds weight, was impregnated with a mixture of three pounds of tallow and three pounds of hemp-seed oil, and put into a baker's oven, which was heated to 90 degrees of Fahrenheit; on taking it out of the oven, an hour afterwards, it was hardly warm. In the space of an hour after this it began to smoke, and in another hour the spontaneous inflammation took place; when M. Georgi observed that it began about the surface, and not in the middle of the mass. He attributed much to the dry wind that blew on that day. The packet burnt for the space of five hours with a visible flame.

Subsequent to these experiments with hemp and flax, this ingenious philosopher made others with wool: he impregnated twenty pounds of wool with a mixture of two pounds of hemp-seed oil, and one of tallow; after having mixed the wool equally with oil, he put it into a small baker's oven, and kept it there for the space of an hour, after which he took it out, and sewed it up in a mat. The packet cooled by degrees, and remained in that state three days, at the expiration of which period the wool was found quite sound and entire, and the fat was so thoroughly imbibed by the wool that it was scarcely perceptible. On the same wool he now poured a pound of hemp-seed oil, and put it again into a baker's oven, of which the heat was 95° of De l'Isle's thermometer. After remaining there an hour, it was tied up in a coarse linen cloth, and laid on some wood in the laboratory. A few hours after, the packet grew warm in some places, and emitted a slight smoke, which increased to that degree that two hours afterwards a spontaneous inflammation took place. The fire glimmered slowly, but when the window was opened it burned for half an hour with a low flame; in the space of forty-four hours it ceased burning, when there remained two pounds and six ounces of coal, and two pounds of very fine ashes.

He made a great many experiments besides, in which the spontaneous inflammation took place, such as steeping cow-hair and wool in oil, and then exposing them to a certain degree of heat, &c. from which may be drawn this general conclusion,

clution, viz. that oils mixed either with vegetable or with animal substances, after they have parted with all their water, begin to take fire. The heat may either have been occasioned by an intestine motion, as is the case when oils are mixed with coarse lamp-black, or with black wad, where, by the internal heat, the whole of the fluid previously evaporates, the inflammation not taking place till the water is evaporated; or else, when vegetable or animal substances are impregnated with oils, when the oil in consequence of the great surface given it parts with its water so much the sooner, and thus acquires a solid and substantial body, with which it can take fire. This inflammation takes place, as Messrs. Hagemann and Geller have observed, in Crell's Chemical Annals, 1784, p. 488, in the apothecaries shops, in oils that are boiled till they are deprived of all their water.

M. Georgi also roasted barley-groats and rice, and he found that the larger the grains are, the less they are disposed to take fire: thus coffee roasted brown and bound up in linen did not kindle; the contrary to which however was the case with ground coffee, which took fire in three quarters of an hour, and continued spreading till half an ounce of ashes remained out of two pounds of coffee. In order to satisfy himself that it was only the size of the coffee-berries that prevented the mutual action of the component parts, the above-mentioned coffee was ground and roasted again tolerably brown, and wrapped up in linen. In an hour after this, the powder took fire. Saw-dust of mahogany-wood was roasted over a gentle fire till it was of a brownish hue, and kindled in a quarter of an hour after it had been wrapped up.

Two pounds of saw-dust of fir-wood, on account of the different size of the particles, became partly black in roasting, and partly white. After being wrapped up, it soon lost its heat; but, an hour after, the heat returned with smoke, when it quickly took fire.

In order to know whether the compression of vegetable substances, and the modification of the air by surrounding them with linen, were essential to the spontaneous inflammation, and whether a spontaneous inflammation would take place without the observance of this circumstance, M. Georgi roasted some barley-coffee till it was brown, which he put into a shallow pot, without covering the latter entirely with its lid. After fourteen hours were elapsed, the warmth of the pot returned, and a smoke arose. There was no fire perceived in the dark; the inside of the pot however had a phosphoric appearance, and paper and bits of wood soon took fire, and a knife, upon being plunged into the mass, became red-hot. In twenty-four hours the fire was extinguished.

The following remark of M. Georgi is of the greatest importance: in the drying of malt, and in roasting of other substances of a similar nature, the malt or other materials may take fire of themselves, in a corner of the kiln, a long time after the operation is finished, and that even in the open air; and, without giving any signs of accension, except a trifling degree of smoke, burn for a considerable time, and do a great deal of mischief.—From all that has been mentioned, it appears that the smaller kinds of grain, as well as flour, saw-dust, and other minutely divided and inflammable substances, when taken in considerable quantities, and united with oily matters, are capable of taking fire themselves under certain circumstances, in consequence of their being surcharged with inflammable particles, as well as of an intestine motion and mutual action in their constituent parts, by which the inflammable particles are disengaged. This is certainly a very remarkable, and hitherto not sufficiently investigated property.



property of many substances appertaining to the vegetable and animal kingdoms, the knowledge of which is very important for the farmer, the manufacturer, and artist.

**PYROTECHNICKS.** The art of making fire-works. In this art the chief objects are to produce a stream of fire, or an explosion. Gun-powder included in a strong paper implement affords the latter effect; the latter is produced by mixing the ingredients of gun-powder together in different proportions, and pulverizing them without wetting. These burn more slowly than grained gun-powder itself. A rocket is formed by ramming this composition into a paper tube, to which an arrow or tail is connected. The explosive stream gives the rocket a progressive motion by its re-action. Rockets are sometimes used in war; but as they are most commonly exhibited for mere amusement, it is usual to include gun-powder in the head of the rocket with balls of a still more slowly burning compound, with additions to vary the colour they exhibit at the instant of explosion, and for a few seconds afterwards.

Lights are also made for signals and station marks. But as all these objects are in some measure remote from the explanation of scientific chemistry, the reader is referred to treatises written expressly on this art. See **ROCKET**.

## Q

## Q U A

## Q U A

**QUADRUM**, a grit stone with a calcareous cement. When it contains about 50 per cent. or more of flint, it belongs to this species; it contains also a small proportion of argill and iron; it hardens by exposure to the air, and then strikes fire with steel, and effervesces slightly with acids: it is sometimes crystallized in rhomboids, as at Fontainebleau. One hundred parts of this contain, by the experiments of Mr. Laffone, 62,5 of flint, and 37,5 of mild calcareous earth.

The *saxum margariticum* of Linnæus belongs also to this species: it consists of quartz in a calcareous cement.

**QUARTATION**, is an operation by which the quantity of one thing is made equal to a fourth part of the quantity of another thing. Thus when gold allayed with silver is to be parted, we are obliged to facilitate the action of the aqua-fortis by reducing the quantity of the former of these metals to one-fourth part of the whole mass; which is done by sufficiently increasing the quantity of the silver, if it be necessary. This operation is called quartation, and is preparatory to the parting; and even many authors extend this name to the operation of parting. See **PARTING**.

**QUARTZ.** Some chemists make a distinction between quartz and rock-crystal. Cronstedt arranges the latter as a species of the former, as does Kirwan also.

In

In general, those crystals of the siliceous order which are clear and perfect and do not crack in the fire, are called rock crystals. See CRYSTAL, ROCK. And those which are coloured, full of flaws, rounded and irregular, are called quartz.

The transparent quartz or rock-crystal is either colourless and crystallized in hexagonal pyramids, and then called mountain crystal, or in various other forms, or irregular. Its specific gravity is from 2,65 to 2,7; its texture is lamellar and generally shattery, and its appearance is glassy. It cracks and loses its transparency when heated; it possesses all the other properties of pure siliceous earth. Bergman has extracted from 100 parts of mountain crystal, about 6 of argillaceous, and 1 of calcareous earth. So also has Mr. Abilgaard, quoted by Kirwan. Yet Gerhard says, that some are so pure as to contain neither. He also says, that the irregular crystals, though colourless, being long digested in acids, afforded, when treated with pure Prussian alkali, some traces of iron.

The purest and most transparent of these crystals form the false diamond, called Bristol, or kerry-stone, diamant d'Alençon, &c.

The coloured transparent crystals derive their tinge generally from metallic particles in exceeding small proportion; they all lose their colour when heated; these form the false gems. The most remarkable are the

Red, from Oran in Barbary; false rubies.

Yellow, from Bohemia; false topazes.

Green; false emeralds and prafes.

Violet, } from Bohemia and Saxony.

Blue, }

It is said that brown crystals may be cleared by boiling them in tallow.

The opaque quartz or pebbles are also crystallized, or irregularly figured, either white, gray, or yellowish, or tinged of other colours by metallic particles. The former are less pure than those of the first series, containing a larger proportion of clay, or at least the clay is less perfectly united with the siliceous part. Their specific gravity is from 2,4 to 2,7; their surface either rough, or smooth and shining, the last are called fat quartz: the texture either lamellar or granular; they crack like the former in fire, and become of a duller colour; when rubbed against each other, they emit a phosphoric smell. They are often found in round masses in the beds of rivers.

The coloured opaque quartz are either, 1. Black, being mixed with a large proportion of iron. 2. Red. According to Cronstedt they contain copper, but Bergman could find none in them. 3. Blue, from Uto in Sweden. And 4. Green, found at Adelsdorf in Sweden.

Though the powdery state of other stones does not deserve any particular notice, yet that of quartz or flint does, from the great use that is made of it, and from its seeming to possess properties which are incompatible with it in a grosser state. It is of various colours, and incapable of forming a mass, or hardening with water. The purest is white, the minute particles of which, when inspected through a lens, are transparent. It is seldom perfectly pure. Mr. Achard says, that the fine white sand of Freyenwald, which is used for the porcelain manufactories, contains  $\frac{1}{3}$  of its weight of clay and calcareous earth; but Kirwan is inclined to suppose, that this is a petro-silex in powder.

QUARTZ, RHOMBIC. See FELT SPAR.

QUERCITRON. Dr. Bancroft has made known the use of the bark of a kind of oak, called yellow oak in New England, and has obtained an exclusive right to the traffick of this bark in France and England: he calls it quercitron.

According to Dr. Bancroft, the quercitron bark may be advantageously sub-



stituted for weld in the printing of linens, but it must be only simply infused in warm water, and only one part employed, instead of ten of weld.

To dye wool yellow, Dr. Bancroft advises that solution of tin and alum should be put into the bath with the quercitron. Silk ought to be treated in the same manner as with weld: if a very bright yellow is required, it must be prepared with solution of tin.

It appears from some information for which Berthollet was indebted to Mr. Brown, that many manufacturers of printed linens in England at present, prefer this bark to weld, because it is considerably cheaper, and the ground whitens more easily. Some find it advantageous to mix a certain proportion of decoction of weld with the quercitron bath, which should be exposed to only a gentle heat. M. D'Ambourney asserts, that, to obtain the advantages set forth by Dr. Bancroft, the wool must be first prepared with solution of tin, and then his process followed.

**QUICK-LIME.** There is in nature a kind of earths and stones, which is susceptible of being changed by the action of fire into the substance called quick-lime, or calx viva; whence those earths and stones are called calcareous, or calcinable. This kind of earth appears to have derived its origin from vegetables and animals, but especially from testaceous animals. It is an earth very much attenuated by the action of organised bodies, and at the same time combined with a certain quantity of water and gas, which make with it an earthy compound of a peculiar nature.

The method of converting earths and stones into quick-lime is very simple. It consists in exposing them to the action of fire, till they become of a white-red heat, and in keeping them in this degree of heat during twelve or fifteen hours. Good quick-lime may also be made with a less heat longer continued, or in less time with a more intense heat; but care must be taken that the heat is not sufficiently violent to vitrify the calcareous stone.

We may know when the calcination is finished by the following signs, which at the same time shew the properties that distinguish quick-lime from uncalcined calcareous earths; and if the calcination is perfect, these properties will be found through the whole substance of the calcined matter.

We may observe that, by calcination, the weight of the stones is reduced to about one half, and that they are rendered more friable.

If the calcined stones be left exposed to the air, they gradually crack and crumble into a fine white powder, called lime slaked in the air. The quick-lime, while it crumbles thus, recovers great part of its original weight before calcination, and, as its parts do not cohere, its bulk is considerably greater than that of the uncalcined stone.

If, while the quick-lime is newly made and very strong, it be put into the water, instead of exposing it to air, it presently cracks and splits with noise: from the crevices thus formed a hot watery vapour exhales, and in a very little time the whole quantity of quick-lime crumbles, and is reduced to as fine a powder as if it had been a long time exposed to the air. All these effects are accompanied with a great heat. When in this experiment a small quantity only of water is used, that is, when no more than the quantity necessary to slake the lime is added, but not enough to dilute it, it becomes a white impalpable powder like that of the lime slaked in the air. But when a larger quantity of it is employed, a white paste results from it, which, although very fine, and cohering in a certain degree, has not the ductility of clay. Water poured copiously

ously on this paste before it dries, easily dilutes it, and the fine particles of the lime may be kept suspended by agitation, and give a milky white appearance to the water. But this earthy powder is soon deposited to the bottom of the vessel in form of a white sediment, and the water above it becomes quite clear. This water, called lime-water, has a very distinct alkaline taste, and which is even acrid. Upon the surface of the water a fine earthy pellicle is gradually formed, called cream of lime. When the pellicle is removed, another will be formed in its place, and thus successively till all the lime which had been dissolved in the water is thus separated.

Accordingly as the earth thus separates from lime-water, this liquor loses gradually its alkaline taste, and lastly becomes quite insipid. On the other side, the cream of lime, which cannot be again dissolved in water, when well washed, has not any alkaline or acrid taste. This decomposition of lime-water does not take place when it is kept in full and well closed bottles.

Calcareous earth, or crude lime-stone, before its calcination, presents none of these phenomena, with air, or with water. It is nearly insipid, and water dissolves scarcely any of it according to Baumé, and none at all according to Lavoisier.

All the acids are capable of dissolving quick-lime, and this solution is accompanied with considerable heat, but without effervescence, or with very little, when the quick-lime is well made. They form with this earth neutral salts, entirely similar to those made with uncalcined calcareous earths: but when the acids unite with these uncalcined earths, they produce a violent effervescence, which they do not, as has been already remarked, with quick-lime.

Lime-water not decomposed, which is nothing else than water saturated with quick-lime, produces the same appearances with acids and other substances as the quick-lime itself, excepting that its combination with these substances is not accompanied with so much heat.

Quick-lime and its solution, that is, lime-water, have not only the taste of acrimony, but likewise the other properties of fixed alkalis; some of which properties, however, are not so strongly marked in quick-lime as in the alkalis. Thus quick-lime changes the blue colour of flowers to a green, precipitates all metallic solutions, and even some salts with earthy bases, such as alum, and decomposes ammoniacal salts, from which it disengages the volatile alkali. It has some action upon oils, spirit of wine, and especially upon sulphur, which it reduces to an hepar, nearly in the same manner as alkalis do. These alkaline saline properties distinguish quick-lime from uncalcined calcareous earths, which, however, in a very small degree, possess some of the same properties.

Fixed and volatile alkalis, treated with quick-lime, become fluor, deliquescent, incapable of effervescing, caustic, and capable of acting like solvents on many bodies, especially those of an oily nature, with much more force and activity than in their ordinary state; and the quick-lime, by thus communicating causticity to alkalis, loses its own causticity, and acquires all the properties of uncalcined calcareous earth.

Quicklime which has been flaked in water, and not long exposed to air, preserves its causticity, at least in a great measure, and the property of rendering alkalis caustic, deliquescent, and incapable of effervescing.

If to lime-water be added, alkalis that are effervescing and not caustic, or the gas which escapes from the effervescence of these alkalis or uncalcined calcareous earth, or the gas of the vinous fermentation; or lastly, if lime-water be mixed



with air that has been respired, or in which any combustion has taken place; this lime-water will be rendered turbid, will be immediately decomposed, the lime will separate from it, and precipitate in the state of an insoluble calcareous earth, deprived of all causticity, effervescing with acids, and perfectly like uncalcined calcareous earths: and it is well worth remarking, that caustic alkalis, whether fixed or volatile, do not precipitate lime-water; but that this water may be precipitated by adding spirit of wine, which spirit not containing any gas, the precipitate produced by its means from lime-water is not in the state of uncalcined calcareous earth, but in the state of quick-lime.

The earthy precipitate obtained from lime-water by effervescing alkalis, or by the several kinds of gas above mentioned, may again recover its causticity, its solubility, and all the other properties of quick-lime, by two methods: 1. By exposing it to fire, in the same manner as calcareous stones are converted into quick-lime; and by this calcination it loses the same proportion of water and of gas as these stones do: 2. By dissolving it in an acid, and precipitating it from the solution by adding a caustic non-effervescing alkali; and in this manner also crude calcareous earths may be converted into quick-lime.

By subjecting calcareous stones to calcination in an apparatus of close vessels, so that whatever is expelled by fire may be obtained, Messrs. Hales, Jacquin and others, and most perspicuously Dr. Black, have shewn, 1. That these stones may be converted into quick-lime without the concurrence of the external air, contrary to the opinion of Van Helmont and of Daniel Ludovic, who had affirmed the contrary, and who considered the calcination of quick-lime as the combustion of an inflammable matter, with which they believed the saline parts of calcareous earths were enveloped. 2. It has been also shewn that, during this calcination in close vessels, a certain quantity of aqueous liquor is expelled from calcareous stones, even although they had been previously well dried. 3. Lastly, it is found, that a considerable quantity of permanently elastic fluid is disengaged during the calcination, and that this vapour is the same as the gas, which is expelled by adding acids to calcareous earth, and which occasions the effervescence that arises upon mixing these substances. See AIR, FIXED.

Quick-lime is of great use in building, as it is the principal ingredient in mortar, which is a mixture of quick-lime slaked with water, and a certain quantity of sand, or of pounded burnt clay. This mixture, when it dries, has the property of becoming solid and hard to a considerable degree, which renders it fit to be used as a cement to bind together the stones of a building.

The cause of the induration of mortar may be naturally deduced from the properties of quick-lime, and especially from the great fineness of its parts when it is slaked. The extreme division of the parts of this stone, which are thus reduced almost entirely to the surface, gives them an opportunity of applying themselves immediately upon the surface of the hard parts of the sand, or burnt clay, and of adhering with a force proportionable to the intimacy of contact.

We cannot doubt that the water, which necessarily enters into the composition of the mortar, contributes also much to its hardness. For if we distil the oldest, hardest and driest mortar with a heat nearly equal to that used in the calcination of lime-stone, a good deal of water is obtained from it, and it loses at the same time its consistence and hardness. We see every day in laboratories an example of what happens to mortar. When lime-water has remained during some time in open vessels, the earth of the lime forms an incrustation on the sides of the vessels; and this incrustated matter adheres so strongly to the sides of the vessel, that it cannot

cannot be disengaged by rubbing, without at the same time wearing off part of the surface of the vessel.

It may be asked, why the dried paste of quick-lime, without addition of sand or burnt clay, does not acquire the consistence and hardness of the mortar, as is well known? This difference proceeds in general from hence, that the parts of the quick-lime can apply themselves sooner to those of hard bodies than they can to each other; but it also appears probable that water contributes greatly to this effect. The phenomena of the extinction of quick-lime in water, and the difficulty ascertained by M. Duhamel's experiments (*Mem. de l'Acad.* 1747) of depriving quick-lime, by means of fire, of all the water it had absorbed during its extinction, demonstrate, that quick-lime contracts a very strong adhesion to water.

The properties of the mortar shew of how much consequence perfect drying is to the goodness of this compound. After many researches into the means of increasing the solidity and hardness of mortar, M. Lorient found, that this effect could be produced by adding to mortar a certain quantity of quick-lime. We cannot doubt that the superiority of this new mortar, over that made in the old way with slaked quick-lime, proceeds from this cause; that the added quick-lime diminishes, as far as is useful, the proportion of the water remaining in the mortar.

Mr. Lorient's mortar is made in the following manner. Take one part of very fine brick-dust well sifted, two parts of fine river sand well screened, and a sufficient quantity of slaked lime, to form a mortar which must be so wet that it can flake a quantity of quick-lime in powder, equal to one fourth of the brick-dust and sand taken together: then add this quick-lime in powder to the brick-dust and sand, incorporate them well with the wet mortar, and use the mixture directly, as the smallest delay may render the use of it defective or impossible.

**QUICKSILVER.** In addition to what has been said on mercury, and the ores of mercury, I shall here add the commercial state of that article, as I find it in Mr. Raspe's Address to the Subscribers of Baron Rork's Work on the Amalgamation of Gold and Silver Ores.

Of the Spanish quicksilver mines in America he observes that he has little to say, except that their produce is more than wholly absorbed by the gold and silver mines in South America; and that Spain, so far from having any quicksilver to export, is on the contrary under the necessity of buying vast quantities to supply the American mines, whose consumption of quicksilver must have been enormous hitherto, as, by their common process of cold amalgamation, they lost 15 oz. for each marc of silver. It is supposed to be annually from 17 to 24,000 quintals (*Ferb. l. i. p. 82*); and as Spain has but lately contracted with the Board of Mining at Vienna for an annual supply of 10,000 quintals of quicksilver from Idria during the course of ten years to come, one may nearly calculate the quicksilver produce of the Spanish mines in America and at Almaden. Whatever it be, the success of the process of amalgamation in Europe must ultimately depend upon the produce of the quicksilver mines in Europe, which are in Friuli, Transylvania, Hungary, Carinthia, Bohemia, the Palatinate, and Zweybruck.

The greatest and most productive of all is that at Idria in Friuli. Formerly its produce was between 2 and 3000 quintals; and though the prime cost was but from 8 to 12 flor. yet by contract almost the whole produce was made over, for interest and part of payment of a sum of money negotiated in Holland, to Messrs. Goll and Company at Amsterdam, at the rate of 150 flor. allowing that House to sell



it at the rate of 200 flor. or 22l. 4s. 5 $\frac{1}{2}$ d. and obliging all the subjects of Austria to buy it at the same price.

When this contract expired, the burthensome debt of Holland being discharged, a lower price, that of 110 flor. was fixed upon for the purpose of underselling the quicksilver mines in the Palatinate and Zweybruck, which cannot raise that commodity under 110 flor.; and the more effectually to prevent their concurrency in the market, 1, 3, and 6 quintals were allowed gratis as an encouragement to the buyers of lots of 100, 200, or 300 quintals. But the public was not benefited by this lower price; nor were the Palatine mines materially hurt or stopt by it, as intended; for Messrs. Verbrug and Gold at Amsterdam, appointed again factors for Idria, took all the quicksilver at that lower price, and raised it as much as they pleased. Such was the state of the quicksilver trade, when the success of amalgamation gave it a new turn, and proved a wonderful encouragement to the quicksilver mines at Idria. The works were pushed and extended with great spirit and exertion, so that the annual produce of Idria is now actually 16,000 quintals; but the tariff and regulations adopted by the Board of Mining at Vienna are rather unaccountable. By a ten years contract with the court of Spain, 10,000 quintals are annually sold to Spain at the rate of 90 flor. or 19l. The Hungarian, Bohemian, and Austrian quickmills are supplied at the rate of 110 flor. or 12l. 8s. Other Austrian subjects, or plate-glass and cinnabar manufacturers, have their supplies at the rate of 150 flor. or 16l. 13 $\frac{1}{2}$ s. sterl. and the rest of Europe at the rate of 167 flor. or 18l. 12s. sterl. From a supposition that thus the sale is perfectly secured to Idria, and from a spirit of monopoly, the Austrian Board of Mining gave now full liberty to work and open other private quicksilver mines in the Austrian dominions, with an offer to take any quantity of their produce at the rate of 100 flor. or 11 $\frac{1}{2}$ l. sterl. by way of pre-emption; which, however, none of these mining companies will make use of, or agree to, as perfectly sure of the better medium price of 150 flor. or 16l. 13 $\frac{1}{2}$ s. sterl. in the general market of Europe, which for the present wholly depends upon the unengaged quicksilver of Idria, the produce of these private mines, and of those in the Palatinate and Zweybruck.

The unengaged quicksilver of Idria is not annually above 4000 quintals.

That of the mines in the Palatinate and Zweybruck is from 800 to 1000.

That of the private mines in Transylvania, and other dominions of the House of Austria, for the present inconsiderable and uncertain; but there is every reason to think that, by more spirited exertion, they will become more productive. They are in various places in Transylvania; in Upper Hungary, near Rosenaw; in Lower Hungary, between Newfol and Cremniz in the Orthuth mountains, where running quicksilver is found in clay immediately under grass, above a seam of coals, as also native cinnabar in quartz; in Carinthia near Neumarktel, and in Bohemia near Shoenfeld, and at Horshoviz and Swata. (Ferb. l. i. p. 143.) Whatever their future produce and the future success of the mines in the Palatinate and Zweybruck may be, it plainly appears that hitherto Austria has wholly regulated the quicksilver price, and to all appearances will regulate it by its very cheap produces at Idria, till these mines shall be exhausted, and till Spain and other kingdoms can provide for themselves. Mr. Raspe concludes by expressing his satisfaction in the hope that Great Britain has a chance also to have quicksilver mines of her own, nor any longer in that respect to be dependent on foreign regulations of finance, speculation, and monopoly.

QUINQUINA. See PERUVIAN BARK.

RAGG-

## R

## R A G

## R A N

**RAGG-STONE.** The colour of this stone is gray; its texture obscurely laminar, but the laminæ consist of a congeries of grains of a quartz appearance, coarse and rough; its specific gravity is 2,779; it effervesces with acids, and gives fire with steel. It is used as a whetstone, frequently without the application either of water or oil.

Whence it comes to us I know not, but its appearance resembles the pumice in every respect except density, in which this greatly exceeds. Its component parts in Kirwan's tables are, 70 flint, 5 clay, 25 mild calcareous earth, and 5 iron, as he thinks.

**RAIN.** See **METEORS.**

**RAINBOW STONE.** See **MOON-STONE.**

**RANCIDITY.** The change which oils undergo by exposure to the air.

Fixed oil, exposed for a certain time to the open air, absorbs the vital part, and acquires a peculiar odour of fire, an acrid and burnt taste, at the same time that it becomes thick and coloured. If oil be put in contact with vital air in a bottle, it becomes more speedily rancid, and the air is absorbed. Scheele observed the absorption of a portion of the air before the theory was well ascertained. Oil is not subject to alteration in closed vessels.

It appears, according to the observation of Chaptal, that vital air combined with the mucilage, constitutes rancidity; and that, when combined with the oil itself, it forms drying oil.

The rancidity of oils is therefore an effect analogous to the calcination of metals. It essentially depends on the combination of pure air with the extractive principle, which is naturally united with the oily principle. This inference is proved by attending to the processes used to counteract or prevent the rancidity of oils.

When olives are prepared for the table, every endeavour is used to deprive them of this principle, which determines their fermentation; and for this purpose various methods are used. In some places they are macerated in boiling water charged with salt and aromatics; and after twenty-four hours digestion, they are steeped in clear water, which is renewed till their taste is perfectly mild. Sometimes nothing more is done than to macerate the olives in cold water; but they are frequently macerated in a lixivium of quick-lime and wood-ashes, after which they are washed in clear water. But in whatever manner the preparation is made, they are preserved in a pickle charged with some aromatic plant, such as coriander and fennel. Some persons preserve them whole; others split them, for the more complete extraction of their mucilage, and in order that they may be more perfectly impregnated with the aromatics.

All these processes evidently tend to extract the mucilaginous principle, which is soluble in water, and by this means to preserve the fruit from fermentation. When the operation is not well made, the olives ferment and change. Chaptal affirms, that, if the olives be treated with boiling water to extract the mucilage before they are submitted to the press, a fine oil will be obtained, without danger of rancidity.

When



When the oil is made, if it be strongly agitated in water, the mucilaginous principle is disengaged; and the oil may be afterwards preserved for a long time without change. The author above mentioned preserved oil of the marc of olives, prepared in this manner, for several years in open bottles without any alteration.

The torrefaction to which several mucilaginous feeds are subjected before the extraction of the oil, renders them less susceptible of change, because the mucilage has been destroyed.

M. Sieffert has proposed to ferment oils with apples or pears, in order to deprive rancid oils of their acrimony. By this means they are cleared of the principle, which had combined with them, but now becomes attached to other bodies.

Mucilage may therefore be considered as the principle of the rancid ferment.

RAPAKIVI. See GRANITE.

REALGAR. See ORPIMENT.

RECEIVER. Receivers are chemical vessels, which are adapted to the necks or beaks of retorts, alembics, and other distillatory vessels, to collect, receive, and contain the products of distillations.

Receivers ought to be made of glass, not only because this matter resists the action of the strongest and most corrosive substances, but also because, being transparent, it allows the operator to see through it, and to judge, by the frequency of the drops, if the distillation be too fast or too slow, and also if the quantity and nature of the substances which come over be such as are required.

Almost all receivers are a kind of bottles of different sizes, of a spherical form, the necks of which are cut short, and each of which is pierced with a small hole in its lateral or upper part, to give vent to the air or vapours, which are too expansive. Receivers of this form are called balloons. See BALLOON.

Some receivers are matrasses with long necks. These are generally adapted to the beaks of glass alembics. This long neck serves to keep the belly of the receiver, where the liquor is collected, at a proper distance from the fire.

Receivers have different forms for particular operations. Such are those which have two or three beaks, either to be adapted to other receivers, or to admit at the same time the necks of several distillatory vessels, when the intention of the operator is, that the vapours of different substances should meet in the same receiver. Such also are receivers for essential oils, which are very convenient for the distillation of these oils. To obtain the essential oil of aromatic plants, these plants must be distilled with water. The plant and the water are to be put together into a cucurbit, and the water, which is to receive a boiling heat, rises in distillation, carrying with it the essential oil, which also has the property of rising with this degree of heat. See OILS.

As a large quantity of water must be employed, that the plant may always be kept immersed in the alembic, and consequently as a good deal of it rises in proportion to the oil, any receiver of ordinary size would be soon filled with water with a little oil floating upon its surface; and would require to be frequently changed, which would be very troublesome, and would occasion a loss of part of the oil.

These inconveniences are avoided by using receivers contrived purposely for such distillations. They are so made, that they are never full, but that the water runs out, and leaves the oil behind. They are a kind of glass cucurbits, which contract as they rise higher; so that their neck, or upper opening, is but nearly  
of

of a convenient size to receive the beak of the worm. These receivers have another opening about the middle of the swelling or belly; and to this opening is joined a glass tube, which bends and rises vertically along the outer part of the receiver, so as to be within two inches and a half as high as the upper opening. At this height the tube bends again towards the side opposite to the body of the receiver, to pour into another vessel the liquor which rises there. It forms the figure of S.

When this receiver is to be used, it is to be placed vertically under the beak of the worm. During the distillation, the liquor rises to an equal height in the body of the receiver and in the crooked tube: when therefore the height of the liquor in the receiver becomes greater than the height of the tube, it must begin to flow from the mouth of this tube into another vessel placed on purpose to receive it: but as essential oils are either lighter or heavier than water, and as they are therefore always collected either above or under the water, and as the liquor which discharges itself through the tube is taken from the middle part of the receiver, therefore nothing but water can be evacuated at the mouth of the pipe, while the oil always remains in the receiver. Thus, with such a receiver, we may distill without the trouble of changing the vessels; which is certainly very advantageous.

**RECTIFICATION.** By rectification is meant the exact purification of certain substances, by means of distillation or sublimation.

This operation is necessary to disengage many chemical products or agents from a mixture of extraneous matters which destroy their purity. Thus, for instance, vitriolic acid, when first obtained from vitriol, or from sulphur, is always charged with a considerable quantity either of inflammable matter, which renders it black and sulphureous; or of superabundant water, which weakens it. It is separated from both these matters by a second distillation, in which they being more volatile than the acid, are carried off; which second distillation is called concentration or rectification of vitriolic acid. See CONCENTRATION OF VITRIOLIC ACID.

Also, when animal and vegetable matters are decomposed by distillation, all the portion of oil that is not volatile, contained in these substances, does not rise but with a degree of fire so strong as to burn a part of them, and to raise along with them a considerable portion of saline substances, which being mixed with the oily part, considerably alter its purity. To purify these oils, which from their burnt smell are called empyreumatic, new distillations must be applied, in which, by means of a less heat, the most volatile and purest part of these oils is separated from the most empyreumatic and saline parts, which remain at the bottom of the retort: this is called the rectification of empyreumatic oils. See OIL.

The ardent spirits obtained by a first distillation of liquors which have undergone the spirituous fermentation are overcharged with a large quantity of phlegm and light oil, which rise along with them in this first distillation. The product of this distillation has been called aqua vitæ. It is an ardent spirit, very far from the degree of dephlegmation and purity which good spirit of wine ought to have to render it fit for chemical operations, and for several compounds commonly used, such as perfumed waters and liqueurs for the table. This spirit of wine is to be purified, or rather the aqua vitæ is to be changed into spirit of wine by new distillations, slowly conducted with a gentle fire and water-bath; by means of which the most volatile part, that always rises first with the least heat, and which is the true



spirit of wine, is separated from the less volatile part that remains in the alembic, and which contains the phlegm and oil of wine by which the spirit of wine was rendered impure. The first liquor of these second distillations or rectifications is called rectified spirit of wine. For its properties see SPIRIT (ARDENT).

When only a small quantity of spirit of wine is to be rectified, the operation is difficult, especially when we would have it perfectly rectified. The cause of this difficulty proceeds from the very small quantity of the first liquor obtained in this rectification. Several chemists, to obtain a larger quantity of the first spirit, propose to mix with the spirit of wine some intermediate substances to absorb and retain its phlegm and oil, such as dried and calcined salts, very dry chalk, &c. Kunckel proposes to separate more effectually the oil, by adding to the spirit a large quantity of water, and by distilling this diluted spirit with a very gentle heat. This method is indeed very capable of facilitating the separation of the oil of wine from the spirit of wine; because this oil certainly adheres to the spirit, which is the chief obstacle to its separation; and because the spirit of wine has greater affinity with water than with oil; so that when it is diluted with much water, it quits the oil to unite with the water. This experiment of Kunckel is therefore very good to facilitate the separation of spirit of wine from the oil which renders it impure; but, on the other hand, when it is practised, we are afterwards obliged to deprive the spirit of wine of the water with which it was diluted.

All this trouble and inconvenience may be avoided by rectifying at once a large quantity of aqua vitæ. Nothing more is required to obtain at once a considerable quantity of pure spirit of wine, than to set aside the twelve or fifteen pints first drawn over from a large quantity, suppose from three hundred pints of aqua vitæ, distilled with a very gentle fire in a large alembic. As the most spirituous, least aqueous, and least oily part of it always rises first, these twelve or fifteen pints are perfectly rectified spirit of wine, especially when the heat has been well conducted. By thus keeping apart portions of the spirit obtained at different times, we may have spirit of wine of the several degrees of strength and purity. The weaker spirit may, by another distillation, be again rectified. Lastly, the spirit of moderate strength may be preserved, as it is fit for many uses. This method is followed by Mr. Baumé in the rectification of spirit of wine, and is certainly the most convenient and the best.

The volatile salts obtained in the decomposition of certain oily substances, as volatile alkalis, from decomposed animal matters, are always very impure, and spoiled by much fetid empyreumatic oil, which rises along with them. They are purified and disengaged by subjecting them to new distillations or sublimations with a well conducted heat. The same observation is applicable to butter of antimony, artificial cinnabar, phosphorus, and to many other chemical products, which are always impure when obtained by a first operation, and must therefore be purified by a second distillation or sublimation. All these second operations, intended merely to purify matters, are called rectifications. They are not generally attended with much difficulty. We shall not therefore enter into the details of them; but we shall only observe, that all rectifications are founded upon the same principle. They all consist in separating substances more volatile from substances less volatile; and the general method of effecting this is to apply only the degree of heat which is necessary to cause this separation. See DISTILLATION and SUBLIMATION.

RED.

**RED CABBAGE.** For the use of this as a test, see **BRASSICA RUBRA**.

**REDDLE, OR RED CHALK,** a calciform ore of iron commonly used as a pigment.

**RED LEAD.** See **MINIUM**.

**REDUCTION, OR REVIVIFICATION.** This word, in its most extensive sense, is applicable to all operations by which any substance is restored to its natural state, or which is considered as such: but custom confines it to operations by which metals are restored to their metallic state, after they have been deprived of this state, either by the combustion of their phlogiston, as the metallic calces, or by the union of some heterogeneous matters which disguise them, as fulminating gold, luna cornea, cinnabar, and other compounds of the same kind. These reductions are also called revivifications. Macquer has explained both these kinds of reduction very perspicuously, as follows:

The reduction of metallic calces regards only imperfect metals; because these alone are susceptible of losing their metallic properties by the loss of phlogiston. They may be deprived of this principle by the action of air or of water, which changes them to rust; or by the action of acids, particularly of the nitrous and virriolic; or lastly, by ordinary calcination, that is, by combustion in an open fire.

Metals deprived of their phlogiston by any of these causes have not their peculiar colour, lustre, ductility, nor even consistence and gravity. They have the appearance of earths, the parts of which are unconnected, unless they have sustained a fire violent enough to fuse them; and then they become brittle vitrified matters.

But these metallic earths, calces, or glasses, are capable of being again restored to the combustible state, and of recovering all the metallic properties. For this purpose their calcination must not have been too complete, and some other combustible matter must be applied in a state favourable for combination. These calces, particularly of such metals as cannot be radically calcined, as lead, bismuth, iron and copper, may recover their combustible state, and may be reduced, even without fire or fusion, merely by the contact of volatile inflammable matter; for instance, by hepatic air of liver of sulphur; or they may be reduced in the humid way, that is, when they are precipitated by some proper substance. See **PHOSPHORUS**, also **PRECIPITATE**.

But we must observe, that metals reduced by either of these methods are only superficially so, when the metallic masses are considerably large; and that when the metals thus reduced consist of fine molecules, these molecules, though well reduced and provided with all their metallic properties, remain always disjoined and separated from each other; either because they are not small enough, or because they have not time to unite and agglutinate together, as they have when they are combined by nature; for metals are certainly formed naturally by these methods: but the operations of our laboratories are very different from those of nature. Accordingly, in practical chemistry a much more expeditious method for making these reductions is employed; which is fusion.

The reduction of metallic calces by fusion is generally a quick and easy operation. It however requires certain attentions and management; which are:

1. To mix accurately the metallic calx to be reduced with the proper quantity of the combustible matter which is to reduce it.
2. To add to the mixture some saline or vitreous matter capable of facilitating the fusion and separation of the reduced metal from the scoria.
3. To prevent any communication with external



air, that the inflammable addition may not be burnt and consumed. 4. To keep the fire low at first, that the too great swelling which is generally occasioned by the extrication of volatile or elastic matter, may be prevented; and to raise the fire towards the end, so that not only the metal, but also the supernatant scoria, may be perfectly fused. For if the scoria was not well fused and tenacious, it would retain much of the reduced metal, and prevent it from falling down to the bottom of the crucible.

The operations must be very exactly performed, especially in essays of ores, in which the precise quantity of metal is required to be known. These essays of ores are in some measure the only reductions of this kind which are performed in practical chemistry, as the reduction of pure metallic calces differs only from the former in requiring a less quantity of flux; because these calces do not, as the ores do, contain a difficultly fusible earthy or stony matter: we therefore refer to the article ORES. Here it may be observed, that when we treat very volatile semi-metals, as zinc and arsenic, the reduction ought to be made in vessels perfectly close; for instance in an earthen retort. We find these metallic matters after the reduction sublimed in the vault or neck of the retort.

The reduction of metals which do not easily lose their combustible state, as gold, silver, and mercury, is of another kind. As these metals can only be disguised by the union they have contracted with some heterogeneous substance, they are to be reduced simply by the addition of some intermediate substance capable of separating from them the matter which is united with them. These intermediate substances must therefore differ according to the matter united with the metal.

For instance, fulminating gold may be reduced by fusing it with sulphur, or with fixed alkali; because either of these substances is capable of separating the volatile alkali, which gives the fulminating property to gold. See GOLD (FULMINATING). Luna cornea also is reduced by fusing it with a large quantity, as for instance with twice its weight of fixed alkali; because in this reduction the marine acid united with the silver is to be separated, and the fixed alkali is capable of effecting that separation. The reduction of luna cornea is attended with difficulties, because this compound is semi-volatile and very penetrating; so that when it is exposed to fire, some part of it is always lost, whether it exhales in vapours or penetrates the crucible. Several chemists recommend the reduction of luna cornea by fusing it with fat matters, which, from experience, Macquer declares to be a very bad method; for the marine acid has a strong affinity with silver, and has no disposition to unite with phlogiston, or even with substances which contain much of it. See SILVER.

Luna cornea may also be well reduced by precipitation, and by treating it with other metals which have more affinity than silver with marine acid, such as tin, iron, regulus of antimony. Margraaf gives, in his *Opuscules Chimiques*, a process which deserves a place here; because, according to this excellent chemist, a very pure silver is obtained, and without any loss. It consists in mixing well in a glass mortar luna cornea with some concrete volatile alkali, in the proportion of above five gros of luna cornea with an ounce and a half of volatile salt, to which a little water is to be added to give to the mixture a soft consistence. The mixture swells with a kind of effervescence. After it has been triturated a quarter of an hour, three ounces of very pure mercury revived from cinnabar are to be added. The trituration is to be renewed for two or three hours, and half a gros of volatile alkali is to be added, to replace that which is dissipated; and after-

wards a larger quantity of water. Upon the addition of this water appears a fine amalgam of silver, which is to be washed several times, till the water comes off clear. This amalgam is then to be distilled; by which the mercury is expelled, and all the silver which was contained in the luna cornea remains pure, excepting about four grains which have been washed away.

The mercury of cinnabar is to be reduced or separated from sulphur, by mixing with the cinnabar any substance which has greater affinity with sulphur than mercury has; such as fixed alkalis, absorbent earths, iron, copper, lead, silver, or regulus of antimony. Filings of iron are generally employed in this operation, an equal weight of which is to be mixed with the cinnabar, and the whole distilled together, by which the mercury will be raised and collected at the bottom of the receiver under some water placed there to facilitate its condensation. The sulphur of the cinnabar remains in the retort united with the intermediate substance employed for the separation. This mercury is called mercury revived from cinnabar; and is justly considered as very pure.

REFINING is a term used in chemistry and several arts to signify the purification of some substance, particularly of metals, as gold, silver, copper, iron, &c.

We shall here treat only of the refining of gold and silver; and for the refining of other substances we refer to their several articles.

Gold and silver may be refined by several methods, which are all founded on the essential properties of these metals, and acquire different names according to their kinds. Thus, for instance, gold, having the property which no other metal, not even silver, has, of resisting the action of sulphur, of antimony, of nitrous acid, of marine acid, may be purified by these agents from all other metallic substances, and consequently may be refined. These operations are distinguished by proper names, as purification of gold by antimony, parting, concentrated parting, dry parting. In a similar manner, as silver has the property, which the imperfect metals have not, of resisting the action of nitre, it may be refined by this salt: but the term refining is chiefly applied to the purification of gold and silver by lead in the cupel. We shall therefore treat only of this latter manner of purifying these metals, referring for the others to the words PURIFICATION and PARTING, which see.

The refining of gold and silver by lead in the cupel is performed by the destruction, vitrification, and scorification of all the extraneous and destructible metallic substances with which they are allayed.

As none but the perfect metals can resist the combined action of air and fire, without burning, that is, without losing their inflammable principle, according to the ancient theory of combustion, or combining with vital air according to the new, and are by that means changed into earthy or vitreous matters incapable of remaining any longer united with substances in a metallic state; there is then a possibility of purifying gold and silver from all alloy of imperfect metals merely by the action of fire and air; only by keeping them fused till all the alloy be destroyed: but this purification would be very expensive, from the great consumption of fuel, and would be exceedingly tedious. Macquer says, he has seen silver allayed with copper, exposed longer than sixty hours to a glass-house fire, without being perfectly refined: the reason of which is, that when a small quantity only of imperfect metal remains united with gold or silver, it is covered and protected from the action of the air which is necessary for the combustion of the imperfect metals, as of all combustible matters. See CALCINATION.

This



This refining of gold and silver merely by the action of fire, which was the only method anciently known, was very long, difficult, expensive, and imperfect: but a much shorter and more advantageous method has been discovered. This method consists in adding to the allayed gold and silver a certain quantity of lead, and in exposing afterwards this mixture to the action of the fire. Lead is one of the metals which loses most quickly and easily, enough of its inflammable principle to cease to be in a metallic state; but at the same time this metal has the remarkable property of retaining, notwithstanding the action of the fire, enough of this same inflammable principle to be very easily melted into a vitrified and powerfully vitrifying matter, called litharge. See LITHARGE.

The lead which is to be added to the gold and silver to be refined, or which happens naturally to be mixed with these metals, produces in their refining the following advantages: 1. By increasing the proportion of imperfect metals, it prevents them from being so well covered and protected by the perfect metals. 2. By uniting with these imperfect metals, it communicates to them a property it has of losing very easily a great part of its inflammable principle. 3. Lastly, by its vitrifying and fusing property, which it exercises with all its force upon the calcined and naturally refractory parts of the other metals, it facilitates and accelerates the fusion, the scorification, and the separation of these metals. These are the advantages procured by lead in the refining of gold and silver.

The lead, which in this operation is scorified, and scorifies along with it the imperfect metals, separates from the metallic mass, with which it is then incapable of remaining united. It floats upon the surface of the melted mass; because, by losing part of its phlogiston, it loses also part of its specific gravity, and lastly it vitrifies.

These vitrified and melted matters, accumulating more and more upon the surface of the metal while the operation advances, would consequently protect this surface from the contact of air which is absolutely necessary for the scorification of the rest, and would thus stop the progress of the operation, which could never be finished, if a method had not been contrived for their removal. This removal of the vitrified matter is procured either by the nature of the vessel in which the melted matter is contained, and which being porous absorbs and imbibes the scorified matters as fast as it is formed; or by a channel cut in the edge of the vessel through which the matter flows out.

The vessel in which the refining is performed is flat and shallow, that the matter which it contains may present to the air the greatest surface possible. This form resembles that of a cup, and hence it has been called cupel. The furnace ought to be vaulted, that the heat may be applied upon the surface of the metal during the whole time of the operation. Upon this surface a crust or dark-coloured pellicle is continually forming. In the instant when all the imperfect metal is destroyed, and consequently the scorification ceases, the surface of the perfect metals is seen, and appears clean and brilliant. This forms a kind of fulguration or coruscation. By this mark the metal is known to be refined. If the operation be so conducted that the metal sustains only the precise degree of heat necessary to keep it fused before it be perfectly refined, we may observe that it fixes or becomes solid all at once in the very instant of the coruscation; because a greater heat is required to keep silver or gold in fusion, when they are pure, than when allayed with lead.

The operation of refining may be performed in small or in large quantities, upon the same principles, but only with some differences in the management.

Large

Large quantities of silver are thus purified, after the operations by which that metal is obtained from its ores. This silver, being always much allayed, is to be mixed with a sufficient quantity of lead to complete its purification, unless lead has been added in its first fusion from the ore, or unless it has been extracted from an ore which also contains lead; in which latter case, it is allayed naturally with a sufficient quantity, or more than sufficient, for the refining of it. See ORES OF SILVER. One of the ores of this kind, which is treated in the best manner, is the ore of Ramelsberg in Saxony. The several operations which are practised in this country, abounding in mines and excellent metallurgists, have been exactly described by Schlutter. We shall here give a succinct extract of the method of purifying large quantities of silver, from Hellot's translation of Schlutter's work.

The workmen give the name of the work to the lead containing silver, obtained by smelting the ore of Ramelsberg. The first operation, called fining, upon this mass of lead and silver, is performed in a furnace called a reverberatory furnace, from the vaulted form, which makes the heat reverberate upon the surface of the metal. This furnace is so constructed, that the flame of the wood, which is put in the fire-place through a hole called the fire-hole, is directed so as to circulate over the work within the furnace. The flame is thus directed by a current of air which is introduced through the ash-hole, and passes out at an opening made at the side of the place where the work is. The wood is considerably saved by this direction of the flame. In the furnace a large cupel or test is to be disposed. This test is to be made with ashes of beech wood well lixiviated, that the salt may be washed from them. See CUPEL. In some founderies different matters are added to the ashes, as sand, lime, clay, calcined spar or gypsum. We may observe, concerning these additions, that they would be very injurious, and would make the test melt, if a strong heat were applied; but the heat requisite for fining is only moderate.

When the test is well prepared and dried, all the work is to be put into it at once, which is generally sixty-four quintals: the fire is then to be made in the fire-place with faggots; but the fusion is not to be too much hastened, first, that the test may have time to dry thoroughly, which is very essential; for if any moisture remained when the metal is melted, an explosion might happen: secondly, because the work of the ore at Ramelsberg, and of most others, is rendered impure by the mixture of many metallic matters, which ought to be separated, otherwise they would spoil the litharge, and give a bad quality to the lead afterwards obtained from that litharge. These extraneous matters found in the work of Ramelsberg are, copper, iron, and matt. As these substances are hard and refractory, they do not melt so soon as the work, if the heat be moderate; and besides, as they are specifically lighter than the mixture of lead and silver, they float upon the surface of these two metals when melted, in form of a pellicle or skin, which is to be taken off. These impurities are called the scum or first dross. The remainder forms also a scum, which appears when the work has received more heat, but before the litharge has begun to form. This is a scoria which is to be carefully taken off, and is called the second dross.

When the operation is come to this point, it is to be continued by means of bellows, the air of which is directed not on the wood, but on the surface of the metals, by means of iron plates placed for that purpose before the blast-hole, and which are called papillons. This air is not intended to increase the fire, but to facilitate the combustion of the lead, and to push the litharge to a channel in the opposite side of the test. This channel is called the way of the litharge, because through this passage



passage all the litharge, which is not imbibed by the test, flows out of the furnace. The litharge which is found in the middle of the largest lumps is friable, and crumbles into powder like sand. It is put in casks, each of which contains five quintals of it, and is sold by the name of saleable litharge. The quantity of this is about one-half or one-third of the whole litharge that is formed. It is used for various purposes, and particularly for glazing earthen ware. The other part which remains is called cold litharge. It is re-melted and reduced to lead. This fusion is called cold fusion, and the lead produced from it, called cold lead, is good and saleable, when the work has been well purified from the extraneous matters mentioned above. The tests impregnated with litharge are added to the same kind of ore when smelted; because they contain not only much litharge which may be reduced to lead, but also some silver, in all refinings, whether in the large or small way, as Mr. Tillet observes.

When about two thirds of the work are converted into litharge, no more litharge is formed: the silver is then covered with a sort of white skin, which the refiners call lightening: and they call the metal lightened silver, or fined silver. The silver thus fined is not pure: every marc of it contains about four gros of lead: the purification of it is completed in the ordinary method; that is, by a second cupellation with a hotter fire; which latter purification is called refining, and the persons who perform it are called refiners. The workmen employed in this first operation or fining give improperly the name lightening to the white skin formed on the surface of the silver, when brought only to a certain degree of fineness; for we know that in essays the lightening or corruscation above-mentioned does not appear but when the silver is perfectly fine, or at least as fine as it can be made by cupellation.

A fining of sixty-four quintals of work of Ramelsberg yields about eight or ten marks of fine silver, thirty-five or forty quintals of litharge, that is, from twelve to eighteen of saleable litharge, from twenty-two to twenty-three of cold litharge, from twenty to twenty-two quintals of tests, and six or seven quintals of dross. The operation lasts from sixteen to eighteen hours.

If the silver before these operations was alloyed by gold, it retains this gold still after the fining and refining. The gold, if the quantity be considerable enough, may be separated by parting. The operations for the purification of gold by cupellation are perfectly the same as those of silver. If the gold to be fined contains silver, this silver remains with it after the operation; because both these metals resist the action of lead. The silver may afterwards be separated by parting.

**REFRACTORY.** This word is applied to infusible substances, or such as cannot be fused by the heat of common furnaces.

**REFRIGERATORY.** A refrigeratory is a copper vessel soldered round the capital of the alembic. Its use is to contain cold water, which is to be renewed when it is heated, and the hot water is to be let out at a cock fitted to the refrigeratory for this purpose. The intention of this renewal of the water of the refrigeratory is to keep perpetually cool the capital of the alembic, that the vapours of the liquor which rise in distillation may be condensed more easily and more quickly. These refrigeratories were much used formerly, and all alembics were furnished with them: but modern distillers find that this vessel is not attended with the advantages it was formerly believed to possess; for the distillation cannot succeed unless the capital of the alembic be as hot, or almost as hot, as the cucurbit. Mr. Baumé observed, that when the capital was cooled by very cold

cold water, the distillation is soon stopped, and does not again begin till the capital is considerably heated.

The refrigeratory has for these reasons been much neglected, and a worm substituted in place of it, which is indeed a kind of refrigeratory, but different from the other in this respect, that it is adapted to the nose of the alembic, instead of surrounding the capital.

This remedy appears however to be in some measure inadequate, because the head produces a considerable return of the spirit, even without a refrigeratory. It seems, nevertheless, that the inconvenience of this last addition arises merely from the large aperture of the neck. See SPIRIT, ARDENT.

REGISTER. Registers are openings in different parts of furnaces, which are to be shut occasionally with stoppers of burnt clay. By means of registers we may govern the fire as we please; for, by opening or shutting them properly, we may not only increase or diminish the activity of the fire, but also we may apply its action more to one part of the furnace than another, by giving direction to the current of air which passes through it. Notwithstanding the utility of registers, they are much neglected. Many chemists have disused registers, probably because they did not find the advantages from them which they expected. The reason of this is, that registers have hitherto been ill made. Their principal fault is, that they are generally too small. A register cannot have its proper effect unless it have an opening of two, three, or four inches for a furnace the internal diameter of which is a foot: but we frequently see furnaces of eighteen or twenty inches in diameter with registers the openings of which are scarcely eight or ten lines. Besides, all those who use furnaces are far from understanding their construction.

REGULUS. The name regulus is given by chemists to metallic matters when separated from other substances by fusion. This name was introduced by all chemists, who, expecting always to find gold in the metal collected at the bottom of their crucibles after fusion, called this metal, thus collected, regulus, as containing gold the king of metals. But although since the cultivation of philosophical chemistry these metallic masses composed of several metals mixed together are occasionally called by this name, yet it is more particularly applied to certain semi-metals which, having no proper name, generally received such as the regulus of antimony, regulus of arsenic, and regulus of cobalt.

RESIN. The name of resin is used to denote inflammable substances soluble in alcohol, usually affording much soot by their combustion; they are likewise soluble in oils, but not at all in water.

All the resins appear to be nothing else but volatile oils rendered concrete by their combination with vital air. The exposure of these to the open air, and the decomposition of acids applied to them, evidently prove this conclusion.

Resins in general are less sweet than the balsams. They afford more volatile oil, but no acid or saline matter, by distillation.

There are some among the known resins which are very pure, and perfectly soluble in alcohol, such as the balm of Mecca and of Copahu, turpentine, tacamahaca, elemi: others are less pure, and contain a small portion of extract, which renders them not totally soluble in alcohol; such are mastic, sandarach, guaiacum, labdanum, and dragon's blood.

1. The balsam of Mecca is a fluid juice which becomes thick and brown by age. It flows from incisions made in the amyris opobalsamum. It is known by



the different names of balm of Judea, of Egypt, of Grand Cairo, of Syria, of Constantinople, &c.

Its smell is strong, and inclining to that of lemons; its taste is bitter, and aromatic.

This balsam, distilled by the heat of boiling water, affords much volatile oil.

It is balsamic, and is given incorporated with sugar, or mixed with the yolk of an egg. It is aromatic, vulnerary, and healing.

2. The balsam of Copahu flows from a tree called Copaiba, in South America, near Tolu. It affords the same products, and possesses the same virtues as the foregoing.

3. The turpentine of Chios flows from the turpentine tree, which affords the pistachios. It is fluid, and of a yellowish-white colour inclining to blue.

This plant grows in Cyprus, at Chios, and is common in the south of France. The turpentine is obtained only from the trunk and large branches. Incisions are made first at the lower parts of the tree, and afterwards by degrees higher up.

This turpentine, distilled on the water-bath, without addition, affords a very white, very limpid, and very fragrant oil: a more ponderous oil may be extracted at the heat of boiling water; and the residue, which is called boiled turpentine, affords by distillation, in the reverberatory furnace, a weak acid, a small quantity of brown consistent oil, and much coal.

The turpentine of Chios is very rare in commerce. Venice turpentine is extracted from the larix; its colour is a bright yellow, its consistence limpid, its smell strong and aromatic, and its taste bitter.

The tree which affords it, is that which affords manna. Holes are bored during the summer near the bottom of the trunks of these trees, into which small gutters or tubes are inserted, to convey the juice into vessels intended to receive it. The resin is obtained only from trees in full vigour; the old trees very often have considerable depositions of resin in their trunks.

This turpentine affords the same principles as that of Chios.

It is used in medicine as a detergent for ulcers in the lungs, kidneys, &c. either incorporated with sugar, or mixed with the yolk of an egg, to render it more miscible with aqueous potions. The soap of Starkey is made with this turpentine. The resin known in commerce by the name of Strasburgh turpentine, is a resinous juice of the consistence of a fixed oil, of a yellowish-white colour, a bitter taste, and a more agreeable smell than the preceding resins.

It flows from the yew-leaved fir, which is very common in the mountains of Switzerland. This resin is collected in blisters, which appear beneath the bark in the strong heats of summer. The peasants pierce these vesicles with the point of a small horn, which becomes filled with the juice, and is from time to time emptied into a larger vessel.

The balm of Canada differs from the turpentine of fir in its smell only, which is more pleasant. It is obtained from a species of fir which grows in Canada.

Oil of turpentine is more particularly used in the arts. It is the great solvent for all resins; and as it evaporates, it leaves them applied to the surface of bodies on which the mixture has been spread. As resins are the basis of all varnishes, alcohol and oil of turpentine must be the vehicles or solvents.

4. Pitch is a resinous juice, of a yellow colour, more or less inclining to brown. It is afforded by a fir named *Picea* or *Epicea*. Incisions are made through the bark; and the wound is renewed from time to time, as the lips become callous. A vigorous tree often affords forty pounds.

Pitch melted and expressed through bags of cloth is rendered purer. It is packed in barrels by the name of white pitch, or Burgundy pitch.

White pitch mixed with lamp black, forms black pitch.

White pitch kept in fusion becomes dry. The desiccation may be facilitated with vinegar; and leaving it for a time over the fire, it then becomes very dry, and is called Colophony.

Lamp-black is the foot of burned pitch. It is likewise prepared by collecting the foot of pit-coal.

5. Galipot is a concrete resinous juice, of a yellowish-white colour, and strong smell. This juice comes from Guieane, where it is afforded by two species of pine, the *pinus maritima*, major et minor.

When these trees have acquired a certain size, a hole or notch is cut through the bark, near the bottom of the trunk. The resin issues out, and flows into vessels placed beneath to receive it. Care is taken to keep the wound open, and to renew it. The resin flows during the summer; but that which issues out during the spring, autumn and winter, dries against the tree.

The pine likewise affords tar, and the oil called *huile de Cade*. For this purpose the wood of the trunk, branches, and roots, is heaped together and covered with turf, over which a fire is lighted, as if to convert them into charcoal. The oil which is disengaged, not being at liberty to escape, falls to the bottom into a channel or gutter, which conveys it into a tub. The most fluid part is sold under the name of *huile de Cade*; and the thicker part is the tar used for paying or painting the parts of shipping and other vessels.

The combination of several resins, coloured by cinnabar and minium, forms sealing wax. To make the wax, take half an ounce of gum-lac, two drams of turpentine, the same quantity of colophony, one dram of cinnabar, and the same quantity of minium. The lac and the colophony are to be first fused, after which the turpentine is to be added, and lastly, the colouring matters.

6. Mastic has the form of white tares of a farinaceous appearance, having little smell, and a bitter astringent taste. Mastic flows naturally from the tree, but its produce is accelerated by incisions. The lesser turpentine tree, and the *lentiscus*, afford that which is met with in commerce.

Mastic affords no volatile oil when distilled with water. It is almost totally soluble in alcohol.

This resin is used in fumigations. It is chewed, to strengthen the gums; and it forms the basis of several drying varnishes.

7. Sandarach is a concrete resinous juice, in dry white transparent tares, of a bitter and astringent taste. It is obtained from most species of the juniper, and is found between the bark and the wood.

Sandarach is almost totally soluble in alcohol, with which it forms a very white varnish, that dries speedily. For this reason, the resin itself is known by the French under the name of varnish (*vernis*). Sandarach is not soluble in olive oil. See SANDARACH.

8. Labdanum is a black resinous juice, dry and friable, of a strong smell, and a disagreeable aromatic taste. It transudes from the leaves and branches of a kind of cistus which grows in the island of Candia. Tournefort, in his voyage



to the Levant, informs us, that when the air is dry, and the resin issues out of the pores of the cistus, the peasants strike all the parts of these trees with a kind of whip, made of several thongs of leather fixed to the end of a staff. The juice adheres to the leather, and is cleared off with a knife. This is pure labdanum, and is very rare. That which is known by the name of labdanum in tortis, is mixed with a very fine ferruginous sand, for the purpose of increasing its weight.

9. Dragon's blood is a resin of a deep red in the mass, but brighter when in powder. It has neither taste nor smell.

It is obtained from the drakena, in the Canary Islands, from which it flows in tares during the dog-days. It is also obtained from the ptero-carpus draco. The parts are exposed to the vapour of hot water; the juice issues out in drops, which are collected and wrapped up in the leaves of reeds.

The dragon's blood of the shops, which has the form of flattened orbicular loaves, is a composition of various gums, to which this form is given, after they have been coloured with a small quantity of dragon's blood.

Dragon's blood is soluble in alcohol: the solution is red: the resin itself may be precipitated of the same colour.

This resin is used in medicine as an astringent.

**RETORT.** Retorts are vessels employed for many distillations, and most frequently for those which require a degree of heat superior to that of boiling water. This vessel is a kind of bottle with a long neck, so bent that it makes with the belly of the retort an angle of about sixty degrees. From this form they have probably been named retorts. The most capacious part of the retort is called its belly. Its upper part is called the arch or roof of the retort, and the bent part is the neck.

Retorts differ in form and materials: their bellies are generally round: some of them are oblong, and shaped like a cucurbit; these are called English retorts. They are preferable for the distillation of matters which are subject to swell, and to pass into the receiver before they be decomposed.

A retort which has a little hole pierced in its roof is called a tabulated retort. This hole must be capable of being exactly closed with a stopper of proper materials. Retorts of this kind are employed in distillations, where some matter must be introduced into the retort after the receiver is joined to it, as in the distillation of smoking marine acid, and in the obsolete operations for procuring the several kinds of clyffus.

If the retort be well made, the above-mentioned inclination of its neck must be most favourable to distillation. When the neck is too much inclined, the receiver cannot be conveniently luted to it, and is also by this form brought too near the furnace. If the neck be too little inclined, the vapours or liquors which rise in distillation can scarcely flow into the receiver from want of sufficient descent, and only circulate in the belly of the retort. Retorts, when too narrow in their bending, are very faulty. This form must be an impediment to distillation: the passage therefore from the belly to the neck of the retort must be free and wide, and gradually diminishing to the extremity of the neck or the mouth of the retort.

Retorts of different materials are used in chemical operations, of common glass, crystal-glass, stone-ware, and iron. Retorts of glass are used for all operations which require a less heat than is sufficient for their fusion. Earthen retorts are necessary where great heat is requisite, as in the preparation of phosphorus.

Iron

Iron retorts are not much used, as they can only serve for the distillation of substances which cannot act upon this metal; and as these substances are few in number, they can seldom be employed but for the distillation of mercury, and of animal matters.

**REVERBERATORY.** See **APPARATUS.**

**REVIVIFICATION.** See **REDUCTION.**

**RHAPONTIC.** The roots of certain docks and some other plants raised in Europe approach to rhubarb in appearance, participate in some degree of its medicinal virtues, and are ranked among the officinal simples, under the names of **MONKS RHUBARB** and **RHAPONTIC.** The common monks rhubarb is the root of the *lapathum hortense latifolium* C. B. broad-leaved garden-dock or patience. The rhapontic of the physick garden of Berlin, and which of all the sorts comes the nearest to the true rhubarb, is the *lapathum folio rotundo alpinum*, J. B. et Tourn. round-leaved mountain or garden-dock. This root is the *rhei rhapontici* of Linnæus. It grows wild on the mountain Rhodope in Thrace, from whence it was brought into Europe, about the year 1610, by Alpinus: it bears the hardest winters of this climate, and is not unfrequent in our botanic gardens. It is of a dusky colour on the surface, and of a loose spongy texture; considerably more astringent, but less purgative than rhubarb.

Sixteen drams of this root yielded Neumann with rectified spirit seven drams and a scruple of extract, and afterwards with water, three drams and a half, five drams and half a scruple remaining undissolved. On inverting the procedure and treating the same quantity of the root first with water and afterwards with spirit, he obtained ten drams two scruples of watery, and one scruple of spirituous extract; the residuum weighed five drams and a few grains.

The extracts made at first, whether by water or by spirit, contain the active matter of the rhapontic, both the second extracts having little or no taste. The yellow colour of the root is more perfectly taken up by spirit than by water, and more concentrated in the spirituous than in the watery extract. The spirituous extract is also stronger in taste than the watery: on first tasting, they both prove sweetish, but soon after discover a degree of pungency.

**RHODIUM LIGNUM**, rose wood, a wood or root brought from the Canary islands; and **aspalathus**, a simple of considerable esteem among the ancients, but which has not come to the knowledge of latter times.

The writers on botany and the materia medica are much divided about the *lignum rhodium*, not only with regard to the plant which affords it, but likewise in their accounts of the drug itself. This confusion seems to have arisen from an opinion that the rhodium and aspalathus are the same; whence different woods brought into Europe for the unknown aspalathus were sold again by the name of rhodium.

As to aspalathus, the ancients themselves disagree; Dioscorides requiring by this appellation the wood of a certain shrub freed from the bark, and Galen the bark of a root. At present we have nothing under this name in the shops: What was heretofore sold among us as aspalathus, were pieces of a pale-coloured wood brought from the East Indies, and more commonly called calambour.

The *lignum rhodium* of the shops is usually in long crooked pieces, full of knots, which when cut appear of a yellow colour like box, with a reddish cast: the largest, smoothest, most compact, and deepest coloured pieces should be chosen; and the small, thin, or pale ones rejected. The taste of this wood is lightly bitterish, and somewhat pungent; its smell very fragrant, resembling that



that of roses: when long kept, it seems to lose its smell; but on cutting or rubbing one piece against the other, it smells as well as at first. Distilled with water, it yields an odoriferous essential oil, in very small quantity. Rhodium is at present in esteem only upon account of its oil, which is employed as an high and agreeable perfume in scenting pomatums and the like. But if we may reason from analogy, this odoriferous simple might be advantageously applied to nobler purposes; a tincture of it in rectified spirit of wine, which contains in small volume the virtue of a considerable deal of the wood, bids fair to prove a serviceable cordial, not inferior perhaps to any thing of this kind.

**RHUBARB.** An ounce of rhubarb, reduced into gross powder, yielded with highly rectified spirit of wine three drams of extract, and afterwards with water two drams two scruples and a half; the residuum weighed two drams twelve grains. By applying water first to another ounce, five drams two scruples and a half of extract were obtained, and of the residuum five grains only were soluble in spirit of wine. Rhubarb appears from these experiments to contain much more gummy or mucilaginous than resinous matter; and hence spirituous tinctures of it are not precipitated or rendered milky by addition of water, like the tinctures of most other vegetables.

The yellow colour of rhubarb is remarkably less destructible than any other vegetable yellows. Aquafortis, and other acids which destroy the colour of saffron, turmeric, &c. make no change in that of rhubarb, or at most render it only turbid. Volatile alkali heightens the colour, and inclines it to red. Fixed alkaline salts have this effect in a greater degree. Solutions of green vitriol and other chalybeate liquors change the colour of infusions of rhubarb to an inky blackness; a mark that this root is possessed of an astringent quality. The spirituous extract does not purge, although the extract made by water after spirit does, as if its purgative quality resided chiefly in a combination of gummy and saline matter. Mr. Model affirms, that a considerable quantity of selenites is contained in rhubarb. In one experiment, he obtained six ounces of selenites from four pounds of rhubarb: and in another experiment he obtained no less than an ounce of selenites from two ounces and five drams of old rhubarb.

**RISIGAL.** See **REALGAR**.

**ROASTING OF ORES.** See the **METALS** and **ORES**.

**ROCK CRYSTAL.** See **CRYSTAL ROCK**, also **QUARTZ**.

**ROCKETS.** In the art of making fire-works, gunpowder constitutes the chief ingredient; but the proportion of it is very frequently varied according to the different uses for which it is intended. For making these, meal-powder only is commonly employed, and mixed with an additional quantity of sulphur and nitre, according to the different purposes for which it is intended; on which account the last ingredient is generally brought into the form of a powder, by solution and evaporation, during which latter operation it is continually stirred.

The mechanical operations of the above-mentioned art not belonging to this work, we shall only make mention of the different compositions which are to be made upon chemical principles, as laid down by Wiegleb. For fuzes, seven parts of meal-powder, five of nitre, and three of sulphur; and for rockets, thirty-six parts of nitre, eight of sulphur, and fourteen of charcoal are to be taken; in both these, the intention is that the powder shall only be fired by degrees. For blue-balls, are to be mixed together thirteen parts of nitre, three of sulphur,  $\frac{1}{2}$  parts of resin,  $\frac{7}{8}$  of saw-dust, and  $\frac{1}{8}$  of charcoal. Light-balls require, for the dry sort, two parts of nitre,  $\frac{1}{2}$  a part of sulphur,  $\frac{3}{8}$  of resin,  $\frac{2}{3}$  of saw-dust, and

and  $\frac{1}{2}$  a part of meal-powder; for the fusible, 8 parts of sulphur, 2 of nitre, and 4 of meal-powder. Fire-balls are composed of twenty parts of corned powder, ten of pitch, six of nitre, four of sulphur, one of tallow, one of hemp, and two of linseed-oil. Water-rockets require eight parts of meal powder, thirty-six of nitre, seven of sulphur, and one of resin. As these particular masses of fire are destined to resist the air and water, and nevertheless to burn for a certain time, the oleaginous and combustible additions are requisite, among which, the intent of the saw-dust appears to be to prolong the conflagration. Among these also may be reckoned the Greek-fire, which in fact was not invented by a Greek, but by Callinicus of Heliopolis, who is said to have used it at the siege of Constantinople. It cannot be decided with certainty what it properly was, or of what it was composed. According to the description of it given in history, it was a liquid substance that was easily kindled, and extinguished with difficulty, which burned upon water, and was thrown inclosed in bottles and pitchers, into the enemies ships, by which means they were set on fire. It is very probable that pitch, sulphur, linseed-oil, oil of turpentine or petroleum made a considerable part of its composition.

The variously coloured fire-works depend on various additions, by which the natural colour of gunpowder, when on fire, may be altered, and in which metallic substances, for the most part, such as antimony, zinc, marcasite, verdigrise, &c. are employed. Thus also clean filings of iron produce what is called brilliant, or white-fire.

**ROD, DIVINING.** The divining wand is an instrument, by means of which many persons have formerly pretended, and some do now pretend, to discover under what parts of the earth metals, treasures, ores, water, salt, &c. lie hid, without digging the ground. They say, this discovery may be made by a person holding the wand horizontally, and by walking along in places where these matters are expected; and that when he arrives at a place under which any of the above-mentioned matters lie, the wand will be forcibly inclined towards that place: but that this experiment should succeed, much faith seems to be required in the person who holds the wand, or rather in the spectators. Macquer positively affirms, that the power of this wand is a chimera, which owes its reputation to avarice, to ignorance and credulity.

The famous Father Kircher, in his *Mundus Subterraneus*, in which many interesting particulars are found concerning mines, derides these superstitious practices, and denies, from his own experience, the truth of the assertions concerning them. He seems however to have some faith in sympathies, and proposes even new divining wands of his own invention; the effects of which, though more dependent on physical causes, are not however more certain. He believes, for instance, that a wand, one end of which should be made of sal-gem, and the other of wood, being suspended and balanced above a mine of salt, would be inclined towards the ground; and he supports his opinion by an experiment. This experiment consists in evaporating over the fire a solution of sal-gem below the wand, which is by no means really made to incline by the salt. We need not be deeply learned in chemistry to discover, that the wand would have inclined in the same manner, if Father Kircher had evaporated pure water, instead of a solution of sal-gem; because the water would have equally well attached itself to the saline end of the wand; consequently this experiment proves nothing.

The same author proposes also to discover mines of mercury by employing a wand, one end of which is made of gold and the other of wood, in hopes that the emanations:



emanations of the mercury would attach themselves to the gold rather than to the wood, and would make it incline downwards. But this effect certainly cannot be produced unless the mercury was evaporating; for which purpose two conditions are necessary: 1. The mercury must be in a native metallic state, and not mineralised, as it is in cinnabar; and 2. It must also be exposed to the heat of some subterranean fire, by which it is volatilised and sublimed, the ordinary heat of the earth being far too little for this purpose. This second physical or chemical divining wand proposed by Father Kircher is therefore no better than the former; and probably the same judgment may be passed upon all other wands made upon the same principles, and in imitation of these. Lastly, the same author positively affirms, that he hung and balanced a wand, one half of which was made of alder tree, and the other half of some wood that has no sympathy with water, over a subterranean water, and that he observed the end of the wand which was made of alder incline towards the earth.

In addition to the above, which is from Macquer, I must remark that the divining rod still possesses considerable reputation among the mere miners in our metallic counties. They pretend to establish, from observation, that the experiment does not succeed unless the rod be held in the hand, or in other words, that an inanimate suspension will not be sufficient to produce the effect: And further, that there are certain individuals in whose hands the rod will be acted upon, but that with far the greater majority it has no effect. I will not here relate any of the narratives which have come to me at second and third hand, wherein very rational precautions are affirmed to have been made in the trials; neither shall I give an opinion where for want of experience I have no good ground to form one. But I think the object is entitled at least to some portion of enquiry, instead of a decided rejection, which might formerly with equal reason have been applied to some of the phenomena of magnetism, electricity, &c.

When we find, for example, that the same electric shock affects one individual strongly, another less, and a third not at all; when we find that the nervous energy is excited, and produces motion in limbs \* recently amputated when certain metals are applied conjunctively and not alone, such as tin and silver, iron and gold, zinc and silver or gold;—when we observe that silver laid upon the tongue, and zinc inserted in the nostril, produce the appearance of a flash of lightning to the living individual the instant they are made to touch; which, though to most persons evident and striking, is much more so to some than to others;—it seems to be not improbable that other energies may exist among metals and minerals, which may shew themselves in the divining rod or otherwise.

**ROOF.** Chemists and metallurgists use this word to denote the internal superior surface of certain cavities. Thus they say the roof of a retort; the roof of a mine, &c.

**ROSEMARY.** This is a native of Spain, Italy, and the southern parts of France, where it grows in abundance upon dry gravelly grounds; in the like soils it thrives best with us, and likewise proves stronger in smell, than when produced in moist rich ones; this observation obtains in almost all the aromatic plants.

Rosemary has a fragrant smell, and a warm pungent bitterish taste, approaching to those of lavender; the leaves and tender tops are strongest; next to these the cup of the flower; the flowers themselves are considerably the weakest, but

\* Valli on Animal Electricity.

most pleasant. Aqueous liquors extract great share of the virtues of rosemary leaves by infusion, and elevate them in distillation; along with the water arises a considerable quantity of essential oil, of an agreeable strong penetrating smell. Pure spirit extracts in great perfection the whole aromatic flavour of the rosemary, and elevates very little of it in distillation: hence the resinous mass left upon abstracting the spirit, proves an elegant aromatic, very rich in the peculiar qualities of the plant. The flowers of rosemary give over great part of their flavour in distillation with pure spirit; by watery liquors their fragrance is much injured; by beating, destroyed. The officinal preparations of rosemary are, an essential oil from the leaves, or from the herb in flower, a conserve of the flowers, and a spirit called hungary-water, from the flowery tops. The tops are used also in the compound spirit of lavender, cordial confection, and saponaceous balsam.

**ROTTEN STONE.** Tripoli; Terra Tripolitana. Is known by its quality of rubbing or wearing hard bodies, and making their surfaces to shine, the particles of the tripoli being so fine as to leave even no perceptible scratches on the surface. This polish may likewise be produced by other fine clays, when they have been burnt a little. The tripoli grows somewhat harder in the fire, and is very refractory: it is with difficulty dissolved by borax, and with still greater difficulty by the microcosmic salt: it becomes white by ignition: when crude, it imbibes water, but is not diffusible in it. It tastes like common chalk, and is rough or sandy between the teeth, although no sand can by any means be separated from it. It has no quality in common with other kinds of earths, by which it might be considered as a variety of any other. That which is here described is of a yellow colour, and is sold by the colourmen, who do not know where it is found.

This earth was formerly brought to us from Tripoli in Barbary, whence this name was given to it. Fabroni enumerates the following characters:

1. This earth does not effervesce with any of the acids: and,
2. It becomes not only hard in the fire; but when considerable heat is applied, its surface becomes vitrified.
3. All tripolis, except those found in England, acquire a red colour by being burnt.
4. They are fusible with the calcareous earth, as well as with borax and with microcosmic salt. But,
5. When washed in water, no other substance separates from them. However,
6. Sometimes the marine acid and the vitriolic may be extracted by distillation from these earths.

It is found either solid, of a rough texture; a brown or yellowish colour; or spotted like marble; or else, friable and compact; of a granulated texture, and brown or yellowish colour. It is this last sort which is found in England.

Da Costa says he has procured the kind of yellow tripoli mentioned by Cronstedt, from Scotland, where it had lately been discovered. But the rotten stone, so called, is another sort, found in Derbyshire. It is in common use here among workmen for all sorts of finer grinding and polishing, and is also sometimes used by lapidaries for cutting of stones.

The rotten stone of Derbyshire is, according to Ferber, a tripoli mixed with calcareous earth.

Kirwan affirms that tripoli is evidently a volcanic product. For a coal mine at St. Estienne having accidentally taken fire, and the fire in its progress having



extended to some strata of shistus and bitumen, tripoli was found in those parts of the strata that the fire had acted upon, but not in any other. *Mém. Par.* 1769. p. 276. quoted by Kirwan.

Tripoli is found also of gray, white, and red colour. It contains 90 parts of siliceous earth, 7 of argill, and 3 of iron. Sometimes a little magnesia has been extracted from it.

ROUCOU. See ANNOTTO, in addition to which article, the following is extracted from Berthollet:

The watery decoction of annotto has a strong smell, and a disagreeable taste; its colour is of a yellowish red, and it is somewhat turbid. An alkaline solution changes it to an orange yellow, which is brighter and more pleasing; and a small quantity of a whitish substance is separated from it, which remains suspended in the liquor. If we boil annotto in water with an alkali, it dissolves much better than in water alone, and the liquor is of an orange colour.

Acids form with this liquor an orange-coloured precipitate soluble in alkalis, which communicate to it a deep orange colour; the supernatant liquor retains only a pale yellow.

Solutions of common salt and sal-ammoniac produce no sensible change.

The solution of alum gives a considerable quantity of orange precipitate, which is deeper than that which acids produce; the liquor remains of a pleasant lemon colour, bordering a little on green.

Vitriol of iron forms a precipitate of an orange brown; the liquor remains of a pale yellow.

Vitriol of copper gives a precipitate of a yellowish brown, somewhat brighter than the former; the liquor preserves a greenish yellow colour.

A solution of tin produces a lemon-coloured precipitate, which is deposited very slowly.

When annotto is used, it is always mixed with an alkali, which facilitates its solution, and gives a colour less inclining to red. It is cut in pieces, and boiled in a caldron, with an equal weight of cendre gravelée, provided the desired shades do not require a smaller proportion of alkali; the cloth may be then dyed in this bath, either with these ingredients alone, or with the addition of others to modify the colour; but it seldom happens that annotto is used for wool, because the colours it imparts are too fading, and may be obtained of a more durable nature by other means. Hellot employed it in dyeing a stuff prepared with alum and tartar, but the permanency of the colour was not much increased. It is almost solely used for silk.

For silks to be dyed of an aurora, or of an orange colour, it is sufficient to scour them with twenty pounds of soap to the hundred; after they have been well cleansed they may be immersed in a bath of water, with which more or less of the alkaline solution of annotto (according to the shade required) has been carefully mixed. The heat of this bath ought to be between tepid and boiling water.

When the silk has acquired an uniform colour, one of the hanks must be taken out, washed and wrung, to see whether the colour be sufficiently full; and if it be not, more solution of annotto must be added, and it must be turned again. This solution preserves its colour unchanged.

When the desired shade has been obtained, nothing remains but to wash the silks, and to beetle them twice, by a stream of water, to free them from the superfluous annotto, which would injure the beauty of the colour.

When

When raw silk is to be dyed, such as is naturally white must be chosen, and it must be dyed in the annotto bath, which ought only to be tepid, or even cold, that the alkali may not dissolve the gum of the silk, and destroy its elasticity, which we wish to preserve.

What has been now said respects the silk intended to receive the aurora colour: to make the orange, which contains more red, after dyeing with annotto, it is necessary to redden the silks with vinegar, alum, or lemon juice. The acid, in saturating the alkali used to dissolve the annotto, destroys the yellow shade which the alkali had imparted, and restores its natural colour, which inclines a good deal towards red.

For the very deep shades it is the practice at Paris, as Macquer informs us, to alum them; and if the colour is not yet red enough, to pass them through a weak bath of brasil-wood. At Lyons, the dyers, who use carthamus, sometimes employ the old baths made with that ingredient for the deep orange colours.

When orange colours have been reddened with alum, they must be washed in a stream of water; but it is not necessary to beetle them, unless the colour be too red.

Shades which preserve a reddish hue may likewise be obtained by a single operation, namely, by employing, in the preparation of the annotto bath, a smaller quantity of alkali than that above directed.

Mr. Gubliche advises us not to employ heat in the preparation of annotto. He directs that it should be put into a glass vessel, or one of earthen ware with a vitreous coat, and that as much solution of pure alkali should be added as will cover it, and that this mixture should be left at rest for twenty-four hours; that the liquor should then be decanted, and filtered, and the residuum repeatedly washed with water, leaving the mixture at rest each time for two or three days, till the water no longer receives any colour; that these liquors should be all mixed together, and put into a well-stopped vessel, and kept for use.

He directs that the silk should be steeped for twelve hours in a solution of alum, in the proportion of two ounces of the salt to a pound of the silk, or in water acidulated with the acetocitric acid before described p. 234; when taken out of this mordant, it is to be well wrung.

The silk thus prepared is put into the annotto bath quite cold, and kept there, and stirred about, until it has acquired the proper shade, or it is kept at a degree of heat far below ebullition; when taken out of the bath, it is washed and dried in the shade.

For the brighter shades, a liquor is employed, which is less loaded with colour, to which may be added a little of the acid liquor, which has been used as a mordant, or the dyed silk may be passed through acidulated water.

If we wish to have the last shades with less of an orange cast, and approaching to nankeen, a small quantity of solution of galls in white wine may be added to the bath.

To give an orange colour to cotton, Mr. Wilson directs the annotto to be ground while it is kept moistened, boiled in water with double its weight of alkali, left to settle for half an hour, and the clear liquor to be put into a heated vessel; in this the cotton is to be immersed, when it will take an orange colour. A hot solution of tartar is then to be poured into the bath, so that it may become weakly acidulated; it is to be again turned in it on the skein sticks, or wound upon the winch when in the piece; in this way the colour becomes more



lively, and fixes better; they then wash the cotton slightly, and dry it in a stove.

**ROWLY RAG.** This stone is of a dusky or dark gray colour, with numerous minute shining crystals. The town of Birmingham is paved with it.

Its texture is granular: by exposure to the air, it acquires an ochrey crust.

Its specific gravity is 2748.

Heated in an open fire, it becomes magnetic.

In strong heat it melts per se, but with more difficulty than basalt.

According to Dr. Withering's analysis, 100 parts of it contain 47,5 of siliceous earth, 32,5 of argil, and 20 of iron.

**RUBICELLE.** See PRECIOUS STONES, No. II.

**RUBY.** See PRECIOUS STONES, No. II.

**RUBY, ARSENICAL.** Realgar, or the red combination of arsenic and sulphur, obtains a degree of transparency by fusion and cooling, and is then distinguished by this name.

**RUST.** Metals are said to rust when their surface becomes calcined by exposure to air and moisture. The calx is also called rust. The word is more particularly applied to iron.

Account of the properties of this substance. Such as it is employed in painting, and in the preparation of colours. The one yellow; the other contains two kinds of colouring matter; the one yellow; the other contains two kinds of colouring matter; its solution is always turbid; with water. The first stone is soluble in water; its solution is always turbid; with water. It exhibits the appearance commonly observed in yellow colouring matter; and more approaching to orange.

It produces a small portion of brown-coloured precipitate, by means of which it becomes clearer. A small portion with a deep yellow precipitate in small quantity; solution of iron, and other metallic solutions, precipitates which have no thing remarkable. Alcohol requires but a slight infusion from the flowers, after all the yellow substance has been extracted by repeated washings. If the flowers be put into a solution of alkali, they become yellow, and the liquor which is pressed out is of a deep yellow colour. On saturating the alkali with a quantity of a reddish becomes turbid, reddish, and gradually becomes a very small quantity of a reddish yellow precipitate.

**SAFFLOWER.** See **CARTHAMUS.**

**SAFFRE.** See **ZAFFRE.**

**SAFFRON.** *Crocus sativus* C. B. et Lin. The chives or fleshy capillaments growing at the end of the pistil of the flower, carefully picked and pressed together into cakes.

There are three sorts of saffron met with in the shops, two of which are brought from abroad, the other is the produce of our own country; this last is greatly superior to the two former, from which it may be distinguished by its blades being broader. When in perfection it is of a fiery orange red colour, and yields a deep yellowish tincture: it should be chosen fresh, not above a year old, in close cakes, neither dry nor yet very moist, tough and firm in tearing, of the same colour within as without, and of a strong, acrid, diffusive smell.

Both water and spirit extract the colour and virtue of saffron. The former liquor improves the smell and heightens the colour, whilst the spirit seems rather to weaken both. By drying two ounces and a half of the best saffron in the heat of a water bath, half an ounce of liquor was obtained, which had an exceeding strong smell, but had not the appearance of oil. This is the active part of the saffron, which disorders the head and senses. Six drams of extract were obtained

from

from an ounce of dried saffron by means of water, and five drams and one scruple were obtained from another ounce by means of spirit. Rectified spirit acquired no smell or taste by distillation from dried saffron; but water being thus distilled acquired a strong smell.

**SAFFRON, BASTARD.** In this article I shall extract the account given by Bertholler, which was not published when the article **CARTHAMUS** went to the press.

Carthamus, or bastard saffron (*carthamus tinctorius*), of which the flower only is used in dyeing, is an annual plant cultivated in Spain, Egypt, and the Levant. There are two varieties of it; one with larger leaves, the other with smaller. The latter is said to be that of Egypt; where it makes a considerable article of trade.

Carthamus was formerly cultivated in Thuringia and Alsatia; but the preference given to that of the Levant has occasioned its culture to be nearly abandoned in the more northern climates. The celebrated Beckmann, who has published a very interesting dissertation on carthamus\*, has endeavoured to discover the difference between that produced with us, and that brought from the Levant: but, previous to his relating his observations, it will not be amiss to give an account of the properties of this substance, such as it is employed in dyeing.

Carthamus contains two kinds of colouring matter; the one yellow; the other red. The first alone is soluble in water: its solution is always turbid: with reagents it exhibits the appearances commonly observed in yellow colouring matter: acids render it lighter; alkalis make it deeper, and more approaching to orange: both produce a small portion of fawn-coloured precipitate, by means of which it becomes clearer. Alum forms with it a deep yellow precipitate in small quantity; solution of tin, and other metallic solutions, precipitates which have nothing remarkable.

Alcohol acquires but a slight tincture from the flowers, after all the yellow substance has been extracted by repeated washings. If these flowers be put into a solution of caustic alkali, they become yellow, and the liquor which is pressed out is of a deep yellow colour. On saturating the alkali with an acid, the liquor becomes turbid, reddish, and gradually deposits a very small quantity of a reddish-yellow precipitate. With solutions of alum, zinc, and tin, a yellow precipitate is formed; and with solutions of iron and copper, a precipitate inclining to green. If instead of a solution of caustic alkali, a solution of mild alkali be used, acids produce with it a more copious precipitate of a redder hue: but the redness differs according to the acid employed. Alum also produces with the latter alkaline solution, a red precipitate, which is so light that it generally swims on the surface of the liquor. This colouring matter is so delicate, and so easily changed, that if heat be employed to dissolve it, the precipitates produced by acids will not have so fine a colour.

Mr. Beckmann has observed, that the carthamus of Thuringia contained much more of the yellow matter than that of the Levant: that, in other respects, the red matter of the former was by no means inferior in beauty to that obtained from the latter; yet that, to produce equal effects, half as much more of it was required. He next examined, whether this difference depended on the climate, or only on the mode of preparation.

Hasselquist relates, in his Travels in Egypt, that when the flowers of carthamus

\* Comment. Societat. Gotting. tom. iv. 1774.



are gathered, they are pressed between two stones, to squeeze out the juice. After this they are washed several times with water, which in Egypt is naturally salt. When taken out of the water they are pressed between the hands, and then spread on mats, placed on the flat roofs of their houses, where they are covered in the day time, that the sun may not dry them too fast, but left exposed to the dew at night. They are occasionally turned, and, when sufficiently dry, taken in, and kept for sale under the name of saffranon.

If the carthamus of the Levant, such as it is in commerce, be compared with that of Thuringia, the former will be found to be more pure, a little moist, and in compressed masses; the latter drier, and more elastic. These differences depend on the preparation. Writers on agriculture, deceived by the erroneous name of bastard saffron given to carthamus, have supposed that it should be treated like saffron. Hence they direct it to be gathered in a dry season, and dried with care. Mr. Beckmann thinks, on the contrary, that the mode adopted in Egypt ought to be imitated. He advises even to add a little salt to the water used in preparing it, to give it the quality it has naturally in Egypt.

The flower of carthamus has a fine colour of fire, but in drying it grows yellow. It should not be gathered till it grows dry; and it is better, if it has been rained upon in that state, though the contrary opinion is erroneously held. The want of rain may be supplied by watering the flowers morning and evening. When they are gathered, the seeds may be still left to ripen.

The intention of these directions is to promote the separation of the yellow matter, the abundance of which constitutes the difference between the carthamus of our climates and that of the Levant. Carthamus should be kept in a moist place, as its becoming too dry would be injurious.

There are many reasons to induce us to enrich our agriculture with this production. The seeds of carthamus are very good food for wild fowl, and particularly for parrots, whence they have received the name of grain de perroquet. An useful oil might be expressed from them, and the residue given to cattle. The dry leaves and stalks would serve as fodder for sheep and goats in the winter; and those stalks which are too large might be used as fuel, after they had stripped them. Mr. Beckmann has found the carthamus ripen well at Gottingen, where the soil is sandy. The ground should be moderately dunged; and the plant neither transplanted nor watered.

No use is made of the yellow substance of carthamus: but to extract that part, it is put into a bag and trodden in water till no more colour can be pressed out. The flowers, which were yellow, become reddish in this operation, and lose nearly half their weight: it is in this state they are used.

The yellow substance might however be employed: and Mr. Poerner has made many experiments on the subject. The principal results of his experiments were, that wool without any preparation takes from it a yellow colour, which is not permanent; but that which it takes after having been prepared with alum and tartar, though not very lasting, is better. Mr. Beckmann asserts, that cloth prepared with tartar, or with tartar and alum, acquires from it a good yellow colour; and that carthamus contains more yellow colouring matter than an equal weight of fustic itself.

To extract the red part of carthamus, and afterwards apply it on the stuff, recourse is had to the property alkalis possess of dissolving it, and it is precipitated by means of an acid. It has been found, that lemon-juice produces the finest colour. Mr. Beckmann says that, next to this, the vitriolic acid produces the best

best effect, provided a proper quantity only be used: too much of it would alter and destroy the colour. According to Scheffer, the juice of the berries of the service-tree (*forbus aucupatorius*) may be substituted for lemon-juice. It is thus prepared. The berries are bruised in a mortar with a wooden pestle, and the expressed juice is left to ferment: it is then bottled, and the clear part, which is most acid, becomes fitter for use the longer it is kept. This operation requires some months, and should be undertaken only in summer.

It has been seen, that the process consists in extracting the red colouring matter by means of an alkali, and precipitating it with an acid. From this precipitate is procured the rouge used by ladies. To make it, the solution of carthamus is prepared with crystals of soda, and precipitated by lemon-juice, which has stood some days to settle. It has been remarked, that lemons beginning to decay were fitter for this purpose than those less ripe, the juice of which retains much mucilage. The precipitate of carthamus is dried on plates of delft with a gentle heat: from these it is separated, and ground very accurately with talc, previously reduced to a very subtil powder by means of the leaves of shave-grass, and passed successively through sieves of different degrees of fineness. The fineness of the talc, and its proportion to the precipitate of carthamus, make the difference between the cheaper and dearer rouges.

Wool may be dyed red by means of carthamus, as Mr. Beckmann has experienced; but this red soon changes towards an orange: and as the finest and most various reds may be obtained from cochineal, which are at the same time much more permanent than those of carthamus, the use of the latter for wool is relinquished.

Carthamus is used for dyeing silk poppy colour, a bright orange red (*macarat*) cherry, rose, and flesh colour. The processes differ according to the intensity of the colour to be given, and the degree in which it approaches that of fire: but the carthamus bath, which varies in the mode of using, is prepared as follows:

After having extracted the yellow matter of the carthamus, and opened the cakes, it is put into a deal trough, where it is sprinkled at different times with soda, or cendres gravelées, the former of which is best, well powdered and sifted, in the proportion of six pounds to a hundred; mixing it well as the alkali is put in. This operation is called *amestrer*. The carthamus thus mixed with the alkali, is put into a small trough with a grated bottom, first lining it with a closely woven cloth. When this trough is nearly half filled, it is placed upon the large one, and cold water is poured on it, till the lower trough is full. The carthamus is then set over another trough, till the water comes from it almost colourless. A little more alkali is then added, and fresh water is poured on. These operations are repeated, till the carthamus is exhausted, and becomes yellow.

The silk being distributed on the rods in hanks, lemon-juice, which comes from Provence in casks, is poured into the bath, till it is of a fine cherry colour. This is called turning (*virer*) the bath. Having stirred the bath well, the silk is dipped in, and turned on the skein sticks as long as it appears to get any colour. For poppy colour, it is taken out, wrung, drained on the pegs, and passed through a new bath, where it is treated as in the former. It is then dried, and passed through fresh baths, washing and drying it after every operation, till it has obtained the depth of colour required. When it is at the proper

point,



point, it is brightened, by turning it seven or eight times in a bath of hot water, to every bucket of which about a gallon of lemon-juice is to be added.

When silk is to be dyed poppy or fire colour, it must be first scoured as for white, and must then have a slight annotto ground, in the manner described in that article. This silk ought not to be alumed.

Bright orange, reds, and deep cherry colours, are treated exactly in the same way as poppy colour, except that they have not the annotto ground, and that they may be dipped in the baths that have been already used for poppy colour, which will exhaust them. Fresh baths are never made for these colours, unless the dyer has no occasion for a poppy.

The lighter cherry colours, rose colours of every shade, and flesh colours, are made from baths of the second and third runnings of the carthamus, which are weaker than the first. In these the deepest shades are first dipped.

The lightest of all these shades, which is a very pale flesh colour, requires a little soap to be put into the bath: this softens the colour, and prevents it from taking too quickly or unevenly. The silk is then washed, and brightened a little in the bath which has been used for brightening the deeper colours.

All these baths are used as soon as they are made, and as quickly as possible, as by keeping they lose much of their colour, which would even be entirely lost after a time. They are also used cold, because the red feculæ lose their colour on being exposed to heat. The reader must have observed, that in the above experiments, caustic alkalis attack the delicate colour of carthamus, and turn it yellow: on this account crystals of soda should be preferred to any other alkali. At least we should choose one that contains most carbonic acid, as salt of tartar.

To lessen the expence of carthamus, it is usual, for deep shades, to mix with the first and second bath about a fifth of the bath of archil.

When raw silk is to be dyed, that which is very white should be chosen and treated as boiled silk, with this difference only, that the poppy colours, bright orange, reds, and cherry colours, are passed through baths that have been used for the same colours for scoured silk, because the raw silk in general takes colours more readily.

Poppy colour prepared in an acid liquor resists the action of vinegar, but it soon changes and fades in the air. Scheffer says, that when he used the juice of services instead of lemon-juice, the colour stood somewhat longer.

Mr. Beckmann has made some experiments on applying the red colour of carthamus to cotton. Having macerated cotton two hours in melted lard, he washed it well, and dyed it in the common way, with carthamus deprived of its yellow matter. This cotton took a deeper colour than some which had undergone no preparation. Soap succeeded equally well; and olive oil still better. Mr. Beckmann then dipped his cotton in oil repeatedly, drying it each time. After the last drying he washed and dried it, and then passed it through the yellow bath of carthamus, to which he added galls and alum. Finally, he dyed it with the alkaline solution of carthamus and lemon-juice. By these means he obtained a fine full red. Cotton treated in the same manner, without having been impregnated with oil, took a colour of the same kind, but less full, and less capable of standing the action of the air. From these experiments he thinks that cotton, to be dyed with carthamus, should receive a preparation similar to that given it for the Adrianople red.

To dye cotton poppy colour, Mr. Willson directs the carthamus, thoroughly freed from the yellow colouring matter, to be put into a vessel, at the bottom of which is a hair sieve, and to pour on it a solution of pearl-ashes, mixing them well, and leaving them to stand all night. The next morning the liquor is to be drawn off by a cock at the bottom of the vessel, and the cotton to be dyed is to be put into it and turned by means of a winch. In the mean time a solution of tartar is prepared, and left to settle; and whilst it is yet hot, it is poured into the carthamus bath, till the liquor is rendered a little sour. The cotton must continue to be turned in this, till it has acquired the proper shade. It is then washed lightly, and dried in a stove. In this way it obtains a fine colour.

To give cotton a scarlet, it must first be dyed yellow in the manner directed under the article ANNORRO, and whilst yet wet, must be dyed with carthamus, in the manner just described. It thus acquires a fine scarlet; but it is not permanent, and will not stand washing.

**SAFFRON OF METALS**, is crude antimony, half deprived of its sulphur and partly calcined by detonation of crude antimony with nitre, and afterwards well washed; or it is liver of antimony deprived of all saline matter by a sufficient washing. This preparation is a violent and uncertain emetic, not used by prudent physicians.

**SAGAPENUM**. A concrete juice brought from Alexandria, either in distinct tears, or run together in large masses. It is outwardly of a yellowish colour; internally, somewhat paler, and clear like horn; grows soft upon being handled, and sticks to the fingers: its taste is hot and biting; the smell disagreeable, by some resembled to that of a leek, by others to a mixture of asafetida and galbanum.

An ounce of the purer sort, examined by Neumann, with rectified spirit of wine yielded in digestion five drams and six grains of resinous extract: the remainder, boiled with water in a close vessel so long as it gave out any thing to the menstruum, yielded five scruples and eight grains of gum, one dram and five grains being left undissolved. Another ounce, treated first with water, gave two drams two scruples and a half of gummy extract; and afterwards with rectified spirit, four drams and one grain of resin, one dram and six grains being left. The distilled spirit is sensibly, and the distilled water strongly, impregnated with the flavour of the sagapenum: along with the water arises a considerable portion of actual oil.

**SAGO**. This is the produce of an oriental tree, called by C. Baubine *pal-mam referens arbor farinifera*. The medullary part of the tree of a middle age or growth, is beaten with water, and made into cakes, which are used by the Indians as bread. They likewise put the powder into a funnel, and wash it with water over a hair-sieve, which allows only the finer part to pass through the water. The water, on standing, deposits the fecula; which being passed through perforated copper-plates is formed into the grains called sago. It forms an agreeable jelly with water, milk, or broth, and is much used in phthical and convalescent cases.

**SAL AMMONIAC**. See AMMONIACAL SALTS.

**SALMIAC**. A word sometimes used for sal ammoniac.

**SALTS**. Salts or saline bodies formerly constituted a principal division of chemical matters. The characters attributed to them were a strong tendency to combination, rapidity, solubility in water, and incombustibility. But the accuracy of modern science has shewn that these properties, and all others which can



be selected to distinguish such bodies which are admitted to be saline, are attended with considerable uncertainty. The tendency to combination is universal, and no less strong in many other bodies than in a large number of the salts. Sapidity is evidently no less general. Solubility in water is scarcely perceptible in a great number of saline compounds, and is a marked character in others not saline, such as ardent spirit, ether, mucilage, serum, and the like. Neither is the incombustibility of salts more exclusive than their other attributes. The mineral kingdom abounds with incombustible matters, which are not salts; and there are salts, such as the acid of benzoin, the volatile alkali, and others more compounded; which are not destitute of this property. The true limits which divide salts from other bodies have not therefore been ascertained. Whence it seems reasonable to infer, not so much the difficulty of the subject, as that the division itself appears to be of little utility.

Solubility in water is retained by modern chemists as a distinctive character of salts, but in an arbitrary and indistinct way. Thus it is remarked, that all bodies known only by the name of salts are soluble in less than two hundred times their weight of boiling water. A surer way of rendering this distinction useful consists in attending to the component parts. Alkalis, acids, and such compounds as they enter into, are distinguished generally by the name of salts. The two former are called simple salts. Compounds of alkali and acid are called neutral salts. Bergman distinguishes the compounds of acid and metal by the name of middle salts, but it may perhaps be more convenient to use the accepted term metallic salts. No appropriate name has been given to the combinations in which the saline character is produced by an alkali without an acid.

An enumeration of all the salts, simple and compound, together with an account of their characters, would comprehend the whole of chemical science. For there are no bodies in nature which are not capable of uniting with some saline substance. We shall, therefore, refer the reader to the articles Acids, and Alkalis, for the properties of those salts, and their compounds; and to the respective earths and metals, for the salts of which they constitute the bases. For a general arrangement or enumeration and their component parts, the article Nomenclature, and the Table of Principles in our Appendix, may be consulted.

**SALT, COMMON.** The crystals of common salt are right-angled six-sided solids, and are usually said to be cubes. These form at the surface, where the evaporation is the greatest; and they float by virtue of the repulsive power of their dry upper surfaces, which displace a quantity of the surrounding water: a circumstance common to all such small bodies as are not easily wetted. When the crystal becomes too large to be suspended in this way, it sinks. If two floating crystals come so near each other as that the hollow spaces may communicate, they fall together into one cavity at the surface, without sinking; and the successive apposition of other crystals often produces a curious hollow pyramid, which is square, because the figure of the crystals themselves occasions them to apply to each other only in the position required to produce such a solid.

Common salt does not alter in the air: but, when exposed to heat, it cracks and flies in pieces, by the escape of its water of crystallization. A greater heat ignites and melts it; and a still greater causes it to rise totally in white fumes. The action of sea-salt upon earths is not considerable. It assists the fusion of siliceous earth; and is thrown into the furnace wherein the pottery called stone-ware is baked, where it rises in fumes, and glazes their surface; probably by the combination of its alkali with the siliceous earth contained in the clay.

Common

Common salt is found in large masses, or in rocks under the earth, in England and elsewhere. In the solid form it is called sal gem or rock salt. If it be pure and transparent, it may be immediately used, in the state in which it is found; but if it contain any impure earthy particles, it should be previously freed from them. In some countries it is found in incredible quantities, and dug up like metals from the bowels of the earth. In this manner has this salt been dug out of the celebrated salt mines near Bochnia and Wieliczka, in Poland, ever since the middle of the 13th century, consequently these 500 years, in such amazing quantities, that sometimes there have been 20,000 ton ready for sale. In these mines, which are said to reach to the depth of several hundred fathoms, 500 men are constantly employed. The pure and transparent salt needs no other preparation than to be beaten to small pieces, or ground in a mill. But that which is more impure must be elutriated, purified, and boiled. That which is quite impure, and full of small stones, is sold under the name of rock salt, and is applied to ordinary uses; it may likewise be used for strengthening weak and poor brine-springs.

Though the salt mines of Wieliczka, near Cracow in Poland, have long astonished the philosopher and traveller, yet it deserves to be remarked, that the quantity of rock salt obtained from the mines of Northwich is greatly superior to that obtained at Cracow. The Bishop of Llandaff affirms that a single pit, into which he descended, yielded at a medium 4000 tons of salt in a year, which alone is about two thirds of that raised in the Polish mines. This rock salt is never used on our tables, in its crude state, as the Polish rock salt is; and though the pure transparent salt might be used with our food, without any danger, yet it is prohibited under a penalty of 40s. for every pound of rock salt so applied. It is partly purified in water, and a great part of it is sent coastwise to Liverpool and other places, where it is used either for strengthening brine-springs or seawater.

Besides the salt mines here mentioned, where the common salt is found in a concrete state, under the name of rock salt, there is at Cordova, in the province of Catalonia in Spain, a remarkable solid mountain of rock salt: this mountain is between four and five hundred feet in height, and a league in circuit; its depth below the surface of the earth is not known. This mountain contains the rock salt without the least admixture of any other matter. Vid. l' Histoire Naturelle de l'Espagne, p. 406; or Dr. Watson's Chemical Essays, vol. ii.

The waters of the ocean every where abound with common salt, though in different proportions. The water of the Baltic sea\* is said to contain one sixty-fourth of its weight of salt; that of the sea between England and Flanders contains one thirty-second part; that on the coasts of Spain one sixteenth part; and between the tropics it is said, perhaps erroneously, to contain from one eleventh to one eighth part.

The water of the sea contains, besides the common salt, a considerable proportion of magnesian marine salt, and some gypsum, or lime combined with vitriolic acid. The magnesian salt is the chief ingredient of the remaining liquid which is left after the extraction of the common salt, and is called the mother water. Sea water, if taken up near the surface, contains also the putrid remains

\* Romé de l'Isle's Crystallographie, vol. i. p. 375, quoted by Magellan in his improved edition of Cronstedt, p. 360.



of animal substances, which render it nauseous, and in a long continued calm, cause the sea to stink.

The whole art of extracting salt from waters which contain it, consists in evaporating the water in the cheapest and most convenient manner. In England, a brine composed of sea water, with the addition of rock salt, is evaporated in large shallow iron boilers; and the crystals of salt are taken out in baskets. In Russia, and probably in other northern countries, the sea water is exposed to freeze; and the ice, which is almost entirely fresh, being taken out, the remaining brine is much stronger, and is evaporated by boiling. In the southern parts of Europe the salt-makers take advantage of spontaneous evaporation. A flat piece of ground near the sea is chosen, and banked round, to prevent its being overflowed at high water. The space within the banks is divided by low walls into several compartments, which successively communicate with each other. At flood tide, the first of these is filled with sea water; which, by remaining a certain time, deposits its impurities, and loses part of its aqueous fluid. The residue is then suffered to run into the next compartment; and the former is again filled as before. From the second compartment, after a due time, the water is transferred into a third, which is lined with clay well rammed and levelled. At this period the evaporation is usually brought to that degree, that a crust of salt is formed on the surface of the water, which the workmen break, and it immediately falls to the bottom. They continue to do this, until the quantity is sufficient to be raked out, and dried in heaps. This is called bay salt.

In some parts of France, and also on the coasts of China, they wash the dried sands of the sea with a small proportion of water, and evaporate this brine in leaden boilers.

There is no difference between this salt and the lake salt extracted from different lakes, excepting such as may be occasioned by the casual intervention of some substances. In this respect the Jeltonic salt-water lake in the Russian dominions near Saratow and Dmitrewsk, deserves our attention. In the year 1748, when the Russians first fetched salt from thence, the lake was almost solid with salt; and that to such a degree that they drove their heavy waggons over it, as over a frozen river, and broke up the salt. But since the year 1757, the water has increased so much, that at this present time it is nothing more than a lake very strongly impregnated with salt. The Jeltonic lake salt contains at the same time alum and Epsom salt.

At several places in Germany, and at Montmarot in France, the waters of salt springs are pumped up to a large reservoir at the top of a building or shed; from which it drops or trickles through small apertures upon boards covered with brush-wood. The large surface of the water thus exposed to the air causes a very considerable evaporation; and the brine is afterwards conveyed to the boilers for the perfect separation of the salt.

The works at Montmarot are thus described by Fourcroy:

The water of the springs is conveyed by pumps into a large reservoir placed at the top of a shed of a peculiar construction. Under this shed are suspended boards covered with little faggots of thorns. The water falling upon those faggots through small cocks, is divided into very minute drops: and as it thus exposes a great deal of surface to the air circulating rapidly under the shed, nearly two thirds of it is evaporated. What is deposited on the faggots is sulphate of lime, or selenite. And when the liquor, upon trial with an instrument for the purpose,

purpose, is found to be charged with salt to a certain degree; it is conveyed into large iron boilers supported by bars of the same metal, which cross the bottom of the vessels, and rest on pieces of wood placed on each side. These boilers, which are called stoves, are very large and shallow, and hold an hundred hogheads of the salt water. They are then urged with a strong fire. When the water boils up in large bubbles, it is at first muddy, and soon deposits an ochreous earth on its surface in the form of a scum. A salt which is scarcely soluble, and is called by the workmen schlot, is next separated: this salt is nothing but sulphate of lime mixed with a little muriate of soda, sulphate of soda, and earthy muriates. See NOMENCLATURE. It is conveyed by the circulation of the boiling liquor into little troughs placed round the sides of the boilers for the purpose. These troughs are taken out and cleared from time to time, till a great quantity of small cubical crystals, called by the workmen pieds de mouches, are observed floating on the surface of the liquor. They are then taken away for the last time. The fire is diminished, and the muriate of soda is taken off with ladles as fast as it is crystallized. The evaporation is thus continued as long as the water continues to afford crystals. The salt thus obtained is in larger or smaller crystals, according to the slowness or rapidity of the evaporation. The water which remains when crystals are no longer obtained, is called mother water, and contains earthy muriates.

Wallerius gives an account of a fourth process for obtaining salt from sea water, which is practised in the north. The water is confined in trenches on the shore: as it forms but a small stratum, the cold soon penetrates through and freezes it. But as that portion necessary for the solution of the salt contained in the whole quantity of water cannot be converted into ice, what remains fluid contains all the salt, and is so concentrated that the most moderate heat causes it to afford muriate of soda in crystals: it is then conveyed into leaden boilers, and evaporated by fire.

The decomposition of common salt, so as to separate the alkali, has not been cheaply enough effected for the purposes of commerce. Litharge unites with the acid, and disengages the alkali. See ALKALI MINERAL, also LEAD. Kirwan has used sugar of lead for the same purpose.

**SALT, SPIRIT OF.** The marine acid was formerly called spirit of salt, but this appellation has long since been disused by philosophical chemists. But it is still the name of the article in commerce. See ACID MARINE.

**SALTPETRE.** See NITRE.

**SAND.** Sand is an assemblage of small stones. It is usually produced by the mechanical division arising from agitation in water. All stones but those of the siliceous order are so soft, that the comminution thus produced is usually carried in them to an extreme degree, so as to form dust or mud, and their disposition to unite or adhere together commonly produces stones of a different texture from that before possessed by the particles. In this way it appears that chalks, clays, marles, and other consistent matters may be formed out of harder or more symmetrical materials worn down. But the siliceous earth being not only very hard, but likewise indisposed to adhere together, retains the form of sand as soon as the parts have become so small as to be deficient in the weight requisite to enable the parts to shake and break each other. Sand is therefore always understood to denote a siliceous matter.

The chief uses of sand in chemistry are in compositions for pottery and glass. Some sands are more and some less fusible, according to the various hard stones from which they may have originated. The size of the particles is of some importance in these works. As an alkali in fusion dissolves siliceous earths in less



time the greater the surface of action; or, which is the same thing, the finer the particles of sand, this kind is accordingly preferred for vitrifications.

**SAND-BATH.** See **BATH**.

**SANDARACH.** A name sometimes given to the combination of arsenic and sulphur. See **ORPIMENT**.

**SANDARACH GUM.** A resin in white tears, possessing a considerable degree of transparency. It is obtained from the juniper tree, in which it occupies a place between the bark and the wood. Its powder is well known by the name of pounce, to be applied to paper when the size has been scraped off by erasion. It is not a pure resin, though water appears to have little if any action upon it. Three or four tears were put into pure ardent spirit. No remarkable appearance happened; but the next day it was found dissolved with a mucilaginous fluid at the bottom of the vessel, which by agitation became uniformly diffused through the fluid, and rendered it semi-opake. Resin is soluble in tallow, by the assistance of heat; but gum sandarach, treated in the same manner, emitted bubbles, swelled up, and enlarged its dimensions greatly; then became brown, imperfectly fluid, and emitted smoke or fume of the peculiar smell of the resin. The tallow did not appear to have suffered any other alteration than that it became brownish. The gum sandarach, apparently not at all dissolved, was crisp or friable.

**SANDIVER, or Glass-gall.** This is a saline matter, which rises as a scum in the pots or crucibles in which glass is made.

This matter is chiefly composed of Glauber's salt, common salt, vitriolated tartar, or other neutral salts which cannot enter into vitrification, and which were originally contained in the ashes or alkalis employed in the composition of glass. Glass-gall is used to facilitate the fusion of certain ores, and in essays; but this matter must vary much, according to the kinds of alkalis or ashes from which it is produced.

**SAP, or water colours,** are of that nature, that they are capable of being entirely dissolved in water, but are by no means miscible with oils. They are of a viscid nature; whence they stand in no need of any cementing substance, neither do they dry easily for this same reason, and are transparent. All colouring juices and extracts inspissated by evaporation may be used with this intention: as for instance, a decoction of brazil-wood prepared with alum, and inspissated; extract of saffron, refined Brunswick green, crystallized verdegrise, an aqueous extract of litmus with the addition of a little alkali, gamboge, fapgreen, and the inspissated decoction of the green husks of walnuts. Of these, fapgreen is prepared from the expressed juice of buckthorn-berries not perfectly ripe (*Rhamnus catharticus* Lin.) by gentle evaporation to the consistence of honey. The sap must be well clarified before it is evaporated. When it is inspissated, as much alum, or, which is still better, sugar of lead, is to be mixed with it by little and little over the fire, as is requisite to produce the finest green colour. A redundancy of these additions is prejudicial. The complete exsiccation must be made with a gentle heat, in saucers. The litmus above mentioned, which however contains a blue sap-colour, is prepared in the large way in the manufactories of Holland. Ferber gives the following description of it: Archil (*Lichen rocella*) is to be mixed with urine, lime-water, slaked lime, and some pot-ash, in several large cisterns, which must be kept under shelter, and suffered to stand for several weeks. By this means the mass is rendered soft, and passes over to a kind of fermentation or evolution of its particles, and of the colouring matter contained in them. Now and then it is stirred, and suffered to stand macerating, till the

mass

mass is become quite blue, and is converted into a muddy kind of pulp. Upon this the whole mixture is ground in a mill constructed for the purpose, and the pulpy magma dried in moulds. Hitherto also may be referred the fine sap-blue discovered by Dr. Struve. In order to make this, a quarter of an ounce of indigo is to be reduced to powder, and triturated in a glass mortar with two ounces of good oil of vitriol. After this, four ounces of alum are to be dissolved in warm water, to which must be added two ounces of a solution of tartar in water, or as much as is requisite for completing the precipitation. The precipitate is then to be edulcorated and filtered; and when it is almost dry, the above-mentioned solution of indigo is to be mixed with it. In this manner is obtained a fine blue colour void of all acrimony, which may be mixed with water ad libitum, and with which silk, leather and bones may be tinged of different shades, and which with some gum forms also a fine sap-colour.

**SAPONARIÆ OFFICINALIS** Lin. Soapwort, bruisewort; the herb and root.

This grows wild, though not very common, in low wet places, and by the sides of running waters; a double-flowered sort is frequent in our gardens. The leaves have a bitter, not agreeable taste; agitated with water, they raise a saponaceous froth, which is said to have nearly the same effects with solutions of soap itself, in taking out spots from clothes, and the like. The roots taste sweetish and somewhat pungent, and have a light smell like those of liquorice: digested in rectified spirit, they yield a strong tincture which loses nothing of its taste or flavour in being inspissated to the consistence of an extract. This elegant root has not come much into practice among us, though it promises from its sensible qualities to be a medicine of considerable utility. It is greatly esteemed by the German physicians as an aperient, corroborant, and sudorific, and preferred by the College of Wirtemberg, Stahl, Neumann, and others, to sarsaparilla. Lewis.

**SAPPHIRE.** See **PRECIOUS STONES**, No. 3.

**SARCOCOLLA** is a gum-resin, of an ounce of which six drams were found to be soluble by spirit of wine; and seven drams and a half were found to be soluble by water. Neumann.

**SARDONYX.** See **PRECIOUS STONES**, No. 20.

**SARSAPARILLA.** From sixteen drams of this root Neumann obtained by water six drams of gummy extract; and from an equal quantity he obtained by spirit four drams of resinous extract.

**SASSAFRAS.** The wood of this tree contains the heaviest of all known essential oils. Of this oil Hoffman obtained an ounce and six drams from six pounds of the wood; and Neumann obtained from an equal quantity of wood, two ounces. From an ounce of sassafras four scruples of extract were obtained by means of rectified spirit; and from an equal quantity of the wood two drams were extracted by water.

**SATURATION.** Some substances unite in all proportions. Such, for example, are acids in general, and some other salts with water; and many of the metals with each other. But there are likewise many substances which cannot be dissolved in a fluid, at a settled temperature, in any quantity beyond a certain proportion. Thus water will dissolve only about one fourth of its weight of common salt; and if more be added it will remain solid. A fluid which holds in solution as much of any substance as it can dissolve, is said to be saturated with



with it. But saturation with one substance does not deprive the fluid of its power of acting on and dissolving some other bodies, but in many cases increases that power. For example, water saturated with salt will dissolve sugar; and water saturated with fixed air will dissolve iron, though without that addition its action on that metal is scarcely perceptible. The word saturation is likewise used in another sense by chemists: the union of two principles produces a body whose properties are different from those of its component parts, but which resemble those of the predominating principle. When the principles are in such proportion as that neither may predominate, they are said to be saturated with each other; but if otherwise, the most predominant principle is said to be under-saturated, and the other over-saturated.

The former kind of saturation is remarked in ether with water, essential oils with spirit of wine, and most neutral salts with water. If we mix together and agitate good ether with water, a part of the ether unites with the water, nearly in the proportion of one to ten; so that if one part of ether be added to ten parts of water, all the ether disappears by being diffused through the water, as the Count de Lauraguais observes. If the quantity of ether be more than one tenth part of the water, the overplus will float distinct upon the surface, like an oil.

Also well rectified spirit of wine can only dissolve a determinate quantity of each kind of essential oil, which quantity varies according to the kind of oil, and to the state in which it happens to be. In general, the more attenuated they have been by rectification, the more they are removed from a resinous state, and the smaller quantity of them is soluble. And also the more highly rectified a spirit of wine is, the larger quantity of oil it dissolves.

Water is the proper solvent of neutral salts. It is capable of dissolving any of them, but most of them only in a certain quantity, and this point of saturation of water differs with different salts and degrees of heat applied. Macquer takes notice that the point of saturation is most distinct with those salts which contain a small quantity only of the water of crystallization, and which are nearly equally soluble in hot and in cold water. Such are vitriolated tartar, and, still more, common salt.

When the water is once saturated with these kinds of salts, the strongest and longest boiling does not dissolve a grain more, and the overplus of the salt remains entire at the bottom of the boiling water: but boiling water dissolves an equal or even an unlimited quantity of some salts, chiefly of those which contain much water in their crystallization, such as Glauber's salt, alum, borax, martial and cupreous vitriols, and others of that kind. The water of crystallization of these salts is alone sufficient to keep them dissolved, by means of heat. Hence, when they are exposed to fire without water, they suffer a liquefaction, which is very different from fusion, and is nothing else than a solution of the salt in the water of its crystallization, and consequently lasts only till this water be evaporated. The point of saturation of water for these salts seems to be indeterminate.

Of those substances which are capable of uniting without being precisely saturated, the most remarkable are, water with the pure acids or alkalis, and ardent spirit with most of the deliquescent salts. Such also are almost all metals uniting with each other: although many of these substances have a great affinity to each other, as the acids and alkalis with water, yet all their general tendency to combination is not exhausted in these kinds of union. On the contrary, in these, the last-mentioned author thinks that their union is little else than a very accurate and intimate mixture. For their dissolving power is not satisfied by such an union,  
but

but is almost entirely preserved. We need not therefore be surprised, that no precise or determinate point of saturation is observed betwixt these substances. We may say, in general, that the point of saturation is so much more exact, distinct, and determinate, as the bodies which unite together have a stronger affinity, as they more completely exhaust upon each other their dissolving power, or as their relative saturation is more nearly equal to their absolute saturation.

The examination of the several degrees of saturation which substances may sustain by combining together, is an object of great importance in chemistry. This matter has been scarcely begun, and yet it well deserves the attention of chemists, as it would greatly advance the science.

**SATURNITE.** By this name Kirwan distinguishes a substance said by Monnet to be found in the lead mines of Poullaouwen in Brittany, and separated from the lead ore during its torrefaction. According to him, it resembles lead in its colour and specific gravity, is soluble in the same acids, and with the same phenomena; but is much more fusible, very brittle, easily scorified and volatilized, and refuses to mix with lead when in fusion. It were to be wished that it was better examined.

**SATYRIUM.** *Orchidis masculæ radix.* Lin. *Orchis:* the root.

This plant is frequently in shady places and moist meadows: each plant has two oval roots, of a whitish colour, a viscid sweetish taste, and a faint unpleasant smell. They abound with a glutinous slimy juice. With regard to their virtues, like other mucilaginous vegetables, they thicken the thin serous humours, and defend the solids from their acrimony: they have also been celebrated, though on no very good foundation, for analeptic and aphrodisiac virtues; and frequently made use of in these intentions.

**SAUNDERS.** The wood of the tree called red saunders contains a red colouring material used in dyeing. Its colour resides wholly in a resinous matter, and hence it is extractable by spirit of wine, and not by water. The red colour of saunders imparted to spirit of wine, becomes, by diluting the tincture with more spirit, yellow. The resin gave a deep red colour to oil of lavender, and a pale red to oil of almonds, and to oil of aniseeds; but no colour to oil of amber and to oil of turpentine. The wood of the tree called yellow saunders is from its fragrance sometimes employed as a perfume. From sixteen ounces of the rasped wood, digested some days in salt water, two drams of essential oil were obtained by cohobation. Two drams of gummy extract may be obtained from two ounces of the wood by water; and from an equal quantity of wood, two drams and a half of resinous extract may be obtained by rectified spirit. Neumann.

**SCAMMONY** is a gummy resinous juice, which exsudes from the root of a species of convolvulus, in which incisions are purposely made at a certain season of the year. An ounce of Smyrna scammony yielded with water half an ounce of gummy extract; and the residuum yielded with spirit two drams of resin, leaving two drams of impurities undissolved. By applying rectified spirit at first to an ounce of the same scammony, two drams and two scruples of resinous extract were obtained; and from the residuum water extracted half an ounce of gum, the indissoluble part amounting here to four scruples only. Neumann.

**SCORDIUM.** An ounce of the dried leaves of scordium yielded with water four drams and a half of gummy extract, and afterwards with rectified spirit fifteen grains of resin. Another ounce, treated first with spirit, gave three drams of resinous extract, and afterwards with water five scruples and a half of gum. A tincture, made in highly rectified spirit of wine, contains more of the active



and less of the mucilaginous parts of this plant, than one made with a weaker spirit.

**SELENITE.** The combination of vitriolic acid and earth. It is plentifully found in nature, and is distinguished by the names gypsum, plaster-stone, alabaster, and gypseous spar, according to its intended use or form. It may be produced by adding diluted vitriolic acid to lime, or to a solution of the nitrous or marine salts with that basis. This earthy salt is one of the least soluble we are acquainted with; four or five hundred times its weight of water are required to suspend it. It is the cause of the property called hardness, in many spring waters, by which term it is generally understood that the water does not lather with soap, nor mitigate thirst as well as that which is purer. By a moderate heat it loses its water of crystallization, and becomes plaster of Paris. A strong heat is required to fuse it alone, but it is more easily fusible in earthy mixtures than pure calcareous earth. See **EARTH calcareous.**

**SEMI-METAL.** See **METALS.**

**SENA.** *Cassia sennæ* Lin. This is a shrubby plant cultivated in Persia, Syria, and Arabia; from whence they are brought, dried, and picked from the stalks, to Alexandria in Egypt, and thence imported into Europe. They are of an oblong figure, sharp-pointed at the ends, about a quarter of an inch broad, and not a full inch in length; of a lively yellowish green colour, a faint not very disagreeable smell, and of a nauseous taste. Some inferior sorts are brought from Tripoli and other places; these may easily be distinguished by their being either narrower, longer, and sharper-pointed; or larger, broader, and round-pointed, with small prominent veins; or large and obtuse, of a fresh green colour, without any yellow cast.

An ounce of choice sena, treated with fresh parcels of rectified spirit of wine, afforded Neumann two drams twenty-three grains of resinous extract; and afterwards with water, two drams two scruples of gummy extract, three drams and three grains remaining undissolved. Another ounce, treated first with water, gave four drams and half a scruple of gummy, and afterwards with spirit only twenty-eight grains of a resinous extract, which appeared to contain some gross oily matter, and hence was with difficulty reduced to dryness; the residuum weighed three drams and a scruple.

In distillation rectified spirit brings over nothing; the distilled water is impregnated with the smell of the sena, but discovers no appearance of essential oil. The activity of the sena is greatly weakened by evaporation, especially if the process is performed by a boiling heat in an open vessel, the extract proving far less purgative than an equivalent quantity of the infusion which it was made from. The resinous extract is more ungrateful in taste than the watery, and contains the green colour of the leaf.

**SENEGAL or SENECA GUM.** Gum Senegal, brought from the island of that name on the coast of Africa, consists of large clear pieces, remarkably transparent when broken, and of a contorted appearance on the surface. It is said to be used as food by the Africans, at least occasionally, in their travels through the deserts. It is not thought to differ from gum Arabic, of which it is said to supply the place in the shops. Gum Senegal is considered as one of the strongest of gums, and forms a considerably thicker or more gelatinous mucilage with water than the rest. The principal consumption of this article is among the calico-printers, who use it to give thickness or body to the solutions which they apply to piece goods by means of stamps or blocks.

**SERPENTINE.**

**SERPENTINE.** Lapis Nephriticus, Gabro of the Italians. In respect to colour as well as composition, this stone is susceptible of great variety; for it is found either white, green, brown, reddish brown, yellow, light blue, black, spotted, or streaked with veins of different colours. Its texture is either indistinct, obscurely laminar, or fibrous. It is harder than soap-rock, but not so hard as to give fire with steel; and less smooth to the touch, but susceptible of a good polish; looks like marble, and is often in thin pieces semi-transparent.

Its specific gravity is from 2.4 to 2.65.

It does not effervesce with acids, but is slowly and partially soluble in them.

It melts per se in a strong heat, and preys on the crucibles. Vogel, 103. In a lower degree of heat it hardens.

According to the analysis of Mr. Bayen, one hundred parts of it contain about forty-one of filex (which he takes rather to be mica), thirty-three of magnesia, ten of argil, twelve of water, and about three of iron. The serpentine of Corfica contains a larger proportion of argil and a smaller of filex.

The greener sorts of this stone have been called nephritic. Their colour arises from manganese. But the term Lapis Nephriticus is commonly applied to **JADE**.

**SHOERL**, a compound stone of the siliceous order, more or less perfectly united to from 0.46 to 0.83 of its weight of argil, from one fourteenth to one ninth of calcareous earth, and to one fifth or one sixth of semiphlogisticated calx of iron, and from one forty-eighth to one fifty-eighth of magnesia.

Its distinguishing properties are, 1st, either a sparry or semi-vitrified appearance, like an enamel or a slag; 2d, a filamentous or scaly texture, which distinguishes it from garnets; the filaments either separate from each other, or conjoined and plated; 3d, fusibility per se in a moderate heat; 4th, a specific gravity from 3 to 3.6, rarely 4.000, and only when loaded with iron; 5th, its hardness nearly equal to that of crystal.

According to Kirwan it has two varieties:

**I. Transparent.** This is always crystallized in some polygonal form; its texture is obscurely sparry; its colour brown, reddish brown, greenish or yellowish brown, or violet: its specific gravity from 3 to 3.6.

A reddish brown prismatic shoerl of this sort, from Vesuvius, contained according to Bergman forty-eight per cent. of siliceous earth, forty of argil, five of calcareous, one of magnesia, and five of iron. The usual fluxes affect this species.

The filamentous sort resembles asbestos, and differs externally only in transparency, and breaking with an even surface.

**II. Opaque.** These are of all colours; white, black, red, brown, greenish, and violet: the filaments are conjoined and parallel, or diverge, as from a common center. Those of a scaly or sparry appearance are generally greenish or black, and are called hornblende. They are frequently crystallized in regular forms, and often so soft as to be scraped with a knife.

An hundred grains of the black crystallized sort from Albano afforded Bergman fifty-eight of filex, twenty-seven of argil, five of calcareous earth, one of magnesia, and 5 of iron. 3 Berg. 207. Other sorts have afforded fifty per cent of siliceous earth, thirty of argil, one or two of magnesia, and eighteen or twenty of iron.

The white sort probably contains less iron.

All these sorts become reddish by calcination.

**Bar shoerl**, Stangen schoerl of the Germans, according to Kirwan was lately found in the Carpathian mountains by Mr. Fichtel, embodied in limestone, and crystallized in prisms; it slightly effervesces with acids.



According to Mr. Binckheim, one hundred parts of it contain 61.6 of siliceous earth, 21.6 of calcareous earth, 6.6 of argil, 5 of magnesia, 1.6 of iron, and 3 of water. 3 *Schrift. Naturforsch. Freunde*, p. 452.

**SIDERITE**, a combination of phosphorus and iron, which is the cause of the cold-short quality of iron, into which it enters as a component part. It was first mentioned as a peculiar metal by Monnet in his Mineralogy; but it was afterwards more particularly examined by Meyer of Stetin and Bergman, who arrived at nearly the same conclusions unknown to each other, but the latter has since proved that it is not a peculiar metal, as was supposed.

Soft iron does not afford it. All the irons of Champagne afford about a dram, or gros, in the pound of iron.

In order to obtain siderite, it is necessary that the solution should be saturated by a gentle heat on the sand bath. If the solution be made too quickly, the siderite is then mixed with ochre, which alters its purity and whiteness.

A precipitate is formed, which takes place so much the more speedily, as the solution is more diluted with water each time after filtration. The precipitate is formed in the first three or four days; a second is obtained towards the sixth day, and that which afterwards falls down is mixed with ochre.

Siderite may likewise be obtained by dissolving iron in the nitrous acid, and evaporation to dryness. The iron is calcined by this first operation. More nitrous acid being poured on this residue, dissolves only the siderite, without touching the calx of iron. A second evaporation must then be made; and the residue must be diluted with water, to evaporate the last portions of nitrous acid; and that which remains is siderite. It is soluble in the vitriolic, nitrous, and muriatic acids, from which it may be precipitated by pouring into the solution as much alkali as is necessary to saturate the acid solvent. If the alkali be added in excess, ochre is then precipitated; and the result is a phosphoric salt, and a salt arising from the union of the acid made use of, and the alkali which has served for the precipitation.

The fixed and volatile alkalis, and lime water, decompose siderite. It is likewise decomposed by projecting it upon fused nitre.

When it has been precipitated by ammoniac, crystals may be obtained by evaporation, which when treated with powder of charcoal afford phosphorus. The ochreous precipitate affords iron by reduction; it is therefore a combination of the phosphoric acid and iron. Every solution of iron is precipitated in the form of siderite by the phosphoric acid.

**SILEX, OR SILICEOUS EARTH.** See **EARTH SILICEOUS**, also **GLASS**. Under this last article I avoided entering into any particular account of the art of glass making, on account of the difficulty of obtaining practical information. Since that time a report has appeared in the *Annals of Chemistry* on a work upon that subject by Mr. Loyfel, drawn up by those excellent chemists Darcet, Fourcroy, and Berthollet, from which, as well for its intrinsic value, as because it is not likely that an English translation will be made, I shall give an extract with very little abridgment.

The art of glass-making, as these chemists observe, is peculiarly capable of being subjected to philosophical principles, and consequently one of those in which the greatest precision might be expected; but to obtain this object it is necessary that the observer should be no less intimately acquainted with all the processes than with the general facts of science. Mr. Loyfel possesses both these qualities. His situation and abilities have long induced him to labour in perfecting this art. Whence they conclude

conclude that an ample extract of his work cannot but be interesting to the French Academy.

Vitrification such as takes place in the large way demands two principal conditions: 1. A furnace constructed of substances capable of resisting the action of a violent and long continued fire, and vessels capable of containing the vitrifiable matter in fusion without becoming fused themselves. 2. Substances which have the property of forming by means of fire a solid glass, suitable to the object of the manufactory.

#### *Of the Furnaces and Crucibles.*

The matter employed for the construction of the furnaces and crucibles must be of such a nature as to take and preserve the forms required for the operations of the glass-house. Clay possesses this property in the highest degree; for which reason, though grit-stone is used in some glass houses, and a mixture of quartz and flint with clay, for the construction of furnaces, it has nevertheless been almost generally adopted for the construction of furnaces, and exclusively for that of the vessels.

Pure clay cannot be fused by any degree of heat yet known; but the mixture of other earths, and particularly calcareous earth, causes it to enter into fusion, though itself alone be infusible. Mr. Lavoisier reports this important observation of Mr. Darcet, which led him to think that the vitrification began with the calcareous earth, acting as a flux to the clay. The reporters mention another explanation of this appearance, by the eminent philosopher and chemist Mr. Laplace. According to this author, a substance is infusible, because its particles remain adherent to each other, and are kept in that state by the force of aggregation which cannot be overcome by the expansive force of heat; so that these two forces may be considered as opposed to each other. If another substance acts by its electric attraction, upon the particles of that which was infusible, it then concurs with the action of the heat to effect a disunion of its particles; and if these three forces be represented by numbers, it will be required to oppose to that number which represents the resistance of aggregation, another number consisting of the sum of those which represent the action of heat, and the electric attraction of the second substance. The academicians think it the more necessary to insist on this explanation, because it is perfectly agreeable to the laws observed in other chemical phenomena. The ancient, but exceptionable adage, "*Corpora non agunt nisi soluta*," cannot be opposed to this doctrine, the truth of which is more particularly evinced by the properties of an alloy, pointed out by Mr. Darcet. This metallic mixture enters into fusion at a degree of heat far below that which is necessary to fuse either of its component parts singly. In this case then it cannot be that the fusion of one of the metals favours that of the two others; but their mutual affinity determines the separation of their particles.

The property of resisting the most extreme heat, is more or less altered in clay, by the admixtures it may contain. Sand, quartz, and mica do not prevent a clay from being proper for the use of the glass-house, provided they do not too greatly diminish its ductility; but the same observation does not apply to bituminous matters, calcareous earth, gypsum, pyrites, or the metallic calces. For these substances render it more or less fusible.

The whitest clay is generally said to be the most refractory; but Mr. Lavoisier remarks that whiteness is a very equivocal character, because it may consist with a large addition of calcareous earth. Now this earth is hurtful, not only because it renders



renders the clay fusible, but because it forms pores in the crucibles by the swelling it occasions when its fixed air is disengaged by the heat. A twentieth part of calcareous earth simply renders the compound less dense than clay alone, when exposed to the fire of the glass-house; but a tenth part renders it sensibly porous.

The choice of a clay in a glass manufactory is of so much the greater consequence, as a failure in this article is attended with a loss of all the expences in fabrication.

The clay to be preferred for this use ought to possess the following qualities: 1. It must be so refractory, as not to vitrify, or even perceptibly change its figure, by the heat of the furnace. 2. It must be ductile enough to receive and retain the requisite forms. The author describes such trials as are necessary to ascertain these two properties.

With regard to the refractory quality Mr. Loyzel proposes three proofs. In the first, after having reduced the clay into small particles, and separated such foreign matters as can be distinguished, the application of a mineral acid will shew whether it effervesces. If it do, there is reason to reject it; but it may be easily seen that this proof is uncertain.

The second proof consists in working the clay into a paste with water. Of this paste, several prismatic rods and some very thin crucibles of five or six inches in diameter, and the same height, are to be made. These, after being gently dried, are to be exposed five or six days in the furnace of the glass-house. The rods must be suspended by their extremities on two supports. When these are taken out, they must be put into the annealing furnace, and cooled by insensible degrees. If the rods have not bended; if the crucibles have preserved their figure, and if no cavities be perceived upon breaking them, the clay may be judged to be good.

The third proof which the author prefers to the others, consists in judging the refractory quality of the clay by the action of an alkali upon it. For this purpose, it is mixed with different doses of fixed alkali, in crucibles of the same earth, or any other of known goodness, and a comparison is made of the proportion necessary to effect a complete vitrification with that which produces the same effect in a refractory sand exposed to the same degree of fire. The author has found, that if eight ounces of alkali be required to vitrify one pound of the sand of Aumont near Senlies, and ten ounces of the same alkali to produce the same effect in a like degree of fire, upon a pound of baked clay, this clay may be employed in the construction of furnaces, and crucibles not intended to undergo a more violent heat than that of the proof, provided its firmness and tenacity be likewise sufficient.

The essay of clays with regard to their tenacity forms the other object of Mr. Loyzel. The solidity of works constructed with clay depends on the force of the cohesion of its parts. This force, when the work has been dried by degrees to a temperature of 25 or 30 degrees of Reaumur, which correspond with the 88th and 107th degrees of Fahrenheit, is so much the greater in proportion to the ductility of clay when in the state of paste; so that both these qualities may be confounded with the tenacity of the clay. But this tenacity is extremely variable. Sand diminishes it more than any other foreign admixture.

All the parts of the furnace of fusion do not require the same tenacity. The thicker parts require many cavities for the dissipation of the moisture; but the crucibles demand a compact and tenacious clay to resist the fluxes, and oppose

the

the pressure of the glass they are to contain. It is of importance therefore to determine the degree of tenacity suitable to each object. Of the different methods tried by Mr. Loyfel, the following succeeded the best:

He forms with the clay intended to be tried, small four-sided rods, which he leaves to dry at the temperature of 25 degrees of Reaumur. He then fashions them, and reduces one of their extremities to a dimension of six lines in each of its four sides. He inserts this extremity into a cubical cavity, and at the distance of eighteen lines he places the knife edge of a balance, into the basin of which he pours sand, until a fracture takes place in that part which is only six lines thick; and from the weight of the balance, the sand, and the broken pieces, he estimates the tenacity of the clay. To avoid accidental irregularities, he repeats the experiment with several of these rods. Hence, he finds that his constructions are solid when the tenacity of the clay prepared for the walls and the arched roof of the furnace of fusion of eight feet diameter, is such, as to resist about twenty-four ounces applied as here described; and for crucibles of three feet in diameter, and three inches and a half thick in the lower part, when it resists fifty-six ounces. But the degrees of tenacity which may be usefully applied, have limits of considerable extent, and may likewise be changed according to the dimensions of the articles. Thus the resistance of a crucible may be increased by adding to its thickness.

When it is known by experience what are the thickness and tenacity of clay, suitable for vessels of a certain dimension, it is easy to determine by computation for other dimensions. The author has given a table for this, viz. the thickness of the lower part of the pots, where the pressure is greatest, whence the thickness diminishes to the rim. At this part, though the pressure vanishes, it is nevertheless necessary, that a certain thickness should be given, that it may dry with regularity, and resist such occasional slight blows as the vessel is likely to receive.

For the most part it is not usual to employ native clay, because it retains moisture very obstinately, is apt to crack, and adheres strongly to the moulds. To remedy this inconvenience, its tenacity is diminished, and its porosity increased, by a mixture either of sand or of baked clay, which is reduced into powder, and improperly called cement. The old crucibles, after a careful separation of such glassy matter as may adhere to them, are used for this purpose; but as these do not furnish a sufficient quantity, other parcels of clay are baked expressly for this use.

Sand greatly diminishes the tenacity, and is most strongly attacked by alkalis. For this reason it is used only in constructions of moderate thickness, the respective parts of which require only a moderate degree of tenacity to support themselves. Such are the walls of the furnace of fusion; but cement is used for several other parts of the furnace, and more especially for the pots.

Glass manufacturers differ in their opinions as to the degree of fineness proper to be given to the cement; but it is easily seen that if the cement be more grossly powdered, the paste will be less homogeneous, more disposed to contract irregularly, and to acquire vacuities into which the fluxes will insinuate themselves. It is requisite therefore, that the cement be reduced to a fine powder, for which purpose it must be passed through very close sieves of silk.

If the tenacity of a mixture of clay and a given quantity of cement be determined, it will be easy to ascertain that of another mixture; for the tenacity of the first mixture will be to that of the second, in the same proportion as the two quantities of clay with that of the cement.

From.



From some inaccuracy in the foregoing paragraph, I confess I do not understand it. I suppose the ratio meant to be expressed is, that if equal quantities of cement be mixed with unequal quantities of clay, the tenacities will be in proportion to these last quantities; and again, as no mention is made of any experiments on which this ratio is established, and as the reasoning, if any, by which it is deduced does not appear, it seems safer at all events for the operator to determine his tenacities by experiment with the particular clay he makes use of, and tabulate them for future reference.

The author has observed, that the proportional tenacities of mixtures determined at a certain degree of heat, continue to be preserved very nearly at every other degree of heat, provided the tenacity of the clay made use of in both mixtures were originally equal.

The contraction which clay undergoes in the fire is subject to great variation in different kinds, and deserves particular attention. Such clays as contract very much, retain water with more force, and are less easily dried; they support the alternations of heat and cold more difficultly; become filled with cracks and clefts, through which the fusible matters penetrate, and appear on the outside in vitrified exsudations. This last inconvenience is more particularly to be feared in such glass works where the pots remain uncovered, as is the case where wood, and not pit-coal, is the fuel. For then the glass which drops from the roof, mixes with the vitrified matter, and produces spots (*larmes*) and veins.

Cement and sand diminish the contraction of clay in proportion to their quantity; but at the same time they diminish its tenacity, and by rendering it more porous cause it to be more easily vitrified by the fluxes. The master of the glass work must determine what mixture is most suitable to his undertaking, by combining these different properties. If he uses covered vessels, he may employ a much greater proportion of sand or cement in the roof of his furnace. There are some who prefer sand to cement; but a distinction must be made as to the degree of fusibility in the clay made use of; for if the cement have more fusibility than the sand, as will happen with clays of middling quality, the sand should then undoubtedly be preferred; but with a good clay, the cement is certainly best.

*Concerning the Construction of the Furnaces for Fusion.*

There are three methods of constructing the furnace of fusion in a glass-house. 1. By using soft bricks. 2. By using bricks dried at the ordinary temperature of the atmosphere. And 3. By using bricks baked in the usual heat of a brick-kiln.

The soft bricks are made as follows: The clay is first dried, and the foreign matters which can be discerned are taken out, for which purpose the pieces must be broken, and examined within. This operation is called in French *l'épluchage de la terre*. If the clay contains much pyrites, the earth is mixed with water, in such a quantity that the mass may be passed through the common sieve of the mealman. The larger pyrites remain behind, and those which come through subside to the bottom with the coarser sand. The mixture is then left to rest, the earth gradually subsides, and the water is from time to time drawn off, by cocks at different heights in the side of the vessel, until the mixture is sufficiently thick to be worked up with the sand or cement. This operation lasts between two and three months; at the end of which time, the matter, rejecting the inferior or lower part, is mixed with the sand or cement into a proper paste. If the clay do not contain pyrites, it is ground without water in a mill under a millstone of

of grit, then sifted and mixed with the sand or cement. Water is then added to convert the whole into a paste; or otherwise the clay purified by the first process of examination is soaked with water for four-and-twenty hours, and mixed with sand or cement.

In whatever manner the paste may have been prepared, it must be of such a consistence, that a ball of lead weighing four ounces may bury itself the depth of its diameter, when let fall out of the hand from an height not less than twenty-four inches, nor more than forty-five.

In this state the bricks would be too soft for the construction of a furnace, and would contract too much in drying. It is necessary therefore, that they be left to dry upon planks of wood. The firmer they are, the better for use, provided they do not break under the mallet of the workman, who strikes them with all his force to unite the different courses together, and to give them the figure required in the different parts of the arch-work. In this state a ball of lead of four ounces will require not less than a height of twenty-five feet, nor more than thirty-five, to bury itself half its diameter in the clay; but a consideration of importance is, that all the bricks ought to be sensibly of the same consistence, in order that the contraction of the different parts of the furnace may be as equal as possible.

The academicians pass over for the sake of brevity the detail into which the author enters, of the method of constructing furnaces with these bricks, and the singular precautions required in their drying.

This method of construction is the best which is known in the glass works. It is attended with the fewest cracks, and endures the longest. It is particularly advantageous in the manufactories of fine glass, and those wherein the vessels are uncovered. Nevertheless it is used only in great establishments. The reason is, that this construction requires more care, time, and expence than any other. It requires likewise a building, in which there are no other furnaces at work, in order that the drying may not be too hasty.

The construction with bricks dried in the air, or baked in the ordinary method, has nothing peculiar in it. This method of building ought to be reserved for glass works where the pots are covered, or for common glass. And even in these, the first method would be found the most advantageous, if the necessary capital be not wanted.

*Concerning the Fabrication of the Vessels or Crucibles.*

The paste or mixture of clay and cement is prepared in the same manner as for the bricks already described, with this difference only, that it must be more consistent. A ball of lead of four ounces weight ought not to fall from a less height than sixty-five inches, nor a greater than eighty-three, to bury itself beneath the surface.

There are two methods of making pots for the glass-house. In the first, a mould of wood is made use of, lined within with a strong and well stretched cloth, and rolls of the paste are applied successively one above the other. In the second method a potter conducts his work without a mould, and joins the rolls of clay together by pressing them strongly between his hands. This second method is considered as better and more exact than the first.

The drying of the pots must be effected in the shade, in a place defended from currents of air, in a temperature of between 10 and 15 degrees of Reaumur, which correspond to the 55th and 65th degrees of Fahrenheit nearly. The drying must be slow, in order that the contraction may be regularly made. It is likewise requisite to defend them from frost and dampness. For this purpose, when the



pots begin to dry, they are put into a close place, where the heat is gradually raised to 25 or 30 degrees. They are then conveyed into the oven called *arche*, which I take to be the annealing furnace above the roof of the furnace of fusion. There they are gradually heated to ignition; after which they are put into the melting furnace, heated less than its usual rate. The fire is successively raised to its greatest degree of heat. In large works, this diminution of the heat lasts three or four hours; but this time is not sufficient to effect a complete drying, for pots of large dimensions. These are usually left empty during the first working of the other pots.

*Concerning the Heat of the Furnaces of a Glass-house.*

Mr. Loyfel establishes with much care the principles, for which we are indebted to modern chemistry, of combustion and the communication of heat, to infer such dispositions as may be most advantageous for the construction of furnaces and management of the fire.

The heat is greater the larger the quantity of air consumed. The entrance of the furnace ought to be therefore entirely free for the access of air; and the vapours of the furnace, which consist in a great measure of air unfit to maintain combustion, ought to be carried off as much as possible. Hence it follows, that the method employed in glass works where pit-coal is the fuel, and in a few others where wood is used, deserves approbation. It consists in establishing a current of air through one or more arched passages, commonly under ground, one of the extremities abutting at the furnace, and the other being placed without the building which contains the furnace, and is commonly called the hall. By this means, several furnaces of fusion may be placed in succession in the same hall, without the combustion of the one being injurious to that of the other, as usually happens in less judicious arrangements. That disposition which approaches nearest to this, is when the doors of the hall are opposite the furnaces; but the most injudicious is that which is commonly employed in glass works where wood is burned. In this, the doors of the hall are on one side. The time required for the fusion and depuration may vary by the difference between the first and the last disposition from 18 to 34 hours.

The air ought to be heated before it arrives at the fire, that its temperature may be less remote from that wherein the combustion is effected. It ought therefore to pass through the ash-hole. Ordinarily in furnaces wherein wood is burned, the current is directed against a small dome above the ash-hole. It ought to be directed immediately into the furnace.

The interior part of the furnace cannot acquire its greatest degree of heat, but in proportion as that which is produced in the fire is deprived of the liberty of escaping during its disengagement. It is even necessary that it should be distributed as equally as possible through the whole interior capacity of the furnace. Now this effect depends on the magnitude and position of the issues of the flame, and the interior figure of the furnace.

It is easy to ascertain by experience in each particular case the proportion which ought to exist between the entrance of the air, and the escape of the flame, by making the apertures of that escape at first larger than necessary, and then diminishing them with moveable bricks disposed for this purpose, until the furnace appears to be in the greatest state of ignition.

The heat is greatest in those parts where the motion of the flame is the most rapid, and this is usually in the vicinity of those apertures to which it is naturally

naturally directed. The equality of the heat of the pots placed round the furnace depends therefore on an equal distribution of the apertures round the same circumference.

The internal figure of the furnace likewise sensibly influences the motion of the flame, and consequently the degree of heat thence arising, as well as the equality of its distribution in the different parts of its capacity. The horizontal section of most of the glass-house furnaces, in France, is a square or rectangular parallelogram in the whole of the part occupied by the pots. Hence it arises that the motion of the flame is checked in the vicinity of the pots placed in the angles; that the heat is less in those than in the other pots, and consequently that with equal mixtures of vitrifiable matter, the glass is not so well refined in the same time as in the other pots, and a greater degree of heat must be used to accomplish this purpose. This produces, 1. a greater expence of fuel; 2. the vitrification and destruction of the dome by excess of heat; and 3. the dome being very much heated, it is necessary that the fire should be slackened in order that the glass may clear itself before the work commences. Mr. Loyfel therefore proposes that the figure of the furnace should be changed, and that it should be formed of a continued curve line like the dome.

The vault or dome of the furnace is the part to which artists pay the greatest attention. Its figure is not the same in all glass-houses; but in a considerable number its generating curve more or less approaches the common parabola. Mr. Loyfel proves from various considerations, that the spherical figure is more advantageous.

Pit coal and wood are equally capable of affording heat not only sufficient for vitrification, but even to alter the figure of the pots. The flame may be more or less charged with sooty matter, which is hurtful in all cases wherein the flame comes in contact with the glass. It colours the vitrifiable matter, and reduces the metallic calces, if such enter into the composition. There are cases wherein the intensity of the heat and the purity of the flame are equally essential, as in the fabrication of glass, where the manipulations require the pots to be uncovered. In other cases the intensity of the heat is the principal condition, as in the glass-works where the pots are covered. In other circumstances again, the purity of the flame requires the utmost consideration, as in the calcination of the frit.

If the colour of the glass be a matter of no consequence, pit coal may be used for all the operations, provided that the metallic calces do not enter into the composition; but if an equally quick fusion be required, with similar doses of fluxing-matter in covered as in uncovered pots, a greater heat must be applied, on account of the resistance opposed to the transmission of the heat by the cover.

Resinous woods afford more smoke than poplars, ash, &c. and these more than birch, oak, sycamore, and beech. The three last are the best for heating the melting furnaces; as well for the purity of the flame, as the intensity of the heat.

In order to obtain the greatest quantity of flame, and the least of smoke, the same quantity of fuel must be constantly kept on the fire. It must therefore be added in small quantities, and at frequent intervals.

It has already been mentioned that Mr. Loyfel, in order to determine the tenacity of different mixtures of clay and cement, and of clay and sand, made use of rods of clay, each face of which was six lines broad; that these rods were dried in the same degree of heat, and afterwards broken by weights suspended at the distance of eighteen lines from the plane of fracture. The author has made experiments to ascertain the proportions of tenacity acquired with the different de-



degrees of heat to which the clay was exposed. With this view he prepared a great number of rods with the same clay, and in each experiment he baked at least four or five in the same degree of heat, to exclude those of which the results might be too discordant, on account of inequality or the variable porosity of the materials.

In this manner Mr. Loyfel made six experiments from 17 degrees of the thermometer of Reaumur, as far as 234; after which having constructed a curve whose ordinates represent the degrees of temperature, and the abscissæ the weights necessary to break the rods, he found that this curve did not sensibly differ from the parabola; and from the equation of this curve, he determines a law between the degrees of temperature and the weights necessary for the fracture.

The degrees of heat which he found immediately by the thermometer, or by the preceding rule, are as follows:

The heat of the apartments in which the unbaked pots are kept ought not to be less than 25 degrees, and sometimes rises as high as 40; that of the *arce* ought not to be higher than this, when the unbaked pots are introduced: it is gradually increased during eight days. At this period the proof of the rods indicated between 900 and 1000 degrees. The lowest heat of a great melting furnace proved to be about 8000 degrees. The most usual heat is about ten or eleven thousand degrees, and ought not to exceed fourteen or fifteen thousand degrees, because at this last temperature, pots of two feet diameter within, and three inches and a half thick, made of good clay, are broken by the pressure of twenty-five inches in depth of glass.

It may be observed that Mr. Loyfel has availed himself of a different property from that used by Wedgwood. See PYROMETER. The first has chosen the tenacity, and the second the contraction of clay, to determine the degree of heat. The second method, as the academicians observe, requires less apparatus; to which we may add, that it appears to depend less on arbitrary dimensions, and indicates minuter differences in less time. But these reporters justly question whether the one or the other method be adequate to prolong the graduation of our thermometers. The heat at which it was possible for Mr. Loyfel to make his comparative experiments, extended no further than from 17 degrees to 234 of Reaumur; a space much too contracted to establish a progression to the extent of 14,000 degrees. As to the agreement of these two methods, Wedgwood (see page 748) remarks that there are three heats in the glass furnaces; a strong heat for vitrification, a low heat for settling, and a greater called the working heat. This last was found in plate glass to be 57° of his thermometer, which we may suppose to correspond with considerable latitude to the ordinary heat of Mr. Loyfel just mentioned. Now Mr. Loyfel's ordinary heat, reduced to the scale of Fahrenheit, is 2340.7°, and the working heat of Wedgwood, according to the same scale, is 916.5°; a difference apparently too great to be admitted without the supposition of error in the parabolic curve of the former, the short intermediate scale of the latter, or, which is still more probable, a change in the measuring property of the clay, at the higher temperatures. It must not however be overlooked, that the heats used in the glass furnaces, and elsewhere, for the same nominal purposes, were found by Wedgwood to differ extremely, though not so much as the preceding numbers do from each other.

#### *Concerning the Vitrification and Vitriifiable Matters.*

The author here describes the siliceous earth distinguished by the name of vitriifiable, and enumerates the metallic and saline fluxes, of which he gives an account

in the following articles. It was obviously unnecessary for the academicians to follow the author in those chemical departments which his plan required him to explain, and accordingly their extract is very properly confined to such parts as are peculiar to the art of glass-making.

*Of the Choice of Vitriifiable Earth.*

The whitest sand is the most frequently mixed with other earthy substances. To clear it of these, it is washed with agitation in clean water. The earthy parts, which are lighter than the sand, remain suspended in the water, which is decanted off, and fresh parcels added till it comes off clear. If it contains combustible matters capable of colouring the glass, it is ignited for the purpose of burning them off. This is the method of purifying the sand for fine glass.

*Of the Metallic Calces considered as Fluxes.*

Of all the metallic calces considered as fluxes of siliceous earth, those of lead are the most used; not only because they are capable of vitrifying a larger dose of this earth, but because they are less costly, and may be employed in considerable proportions without injuring the whiteness of the glass. Minium is preferred to any other calx of lead. If it be used with the vitriifiable earth of pulverized flints, or the white sand of Aumont near Senlis, five pounds of minium cannot completely vitrify more than two pounds of this earth in the ordinary fire of the glass-house. The glass which results is of an orange yellow, and full of veins; and specifically near five times as heavy as water. If the dose of earth be smaller, the vitrification is more speedy, and the glass is more coloured and heavy. The greater proportion of calx of lead which enters into a composition, the less brittle the glass proves by the alternations of heat and cold. The more on the other hand the vitriifiable earth predominates, the glass will be more white, transparent, light, subject to break by sudden change of temperature, and difficult to soften by heat. The proportions of calx of lead and sand must therefore be varied according to the object desired.

*Concerning Arsenic.*

The use of arsenic is avoided in glasses which contain calx of lead, because this material favours its sublimation. The most effectual, as well as the most common method, is to mix nitre along with the vitriifiable materials. A large dose of arsenic gives a milky appearance to glass, and may even render it entirely opaque. As glass is sometimes capable of being attacked by acids, it is proper to avoid arsenic in all vessels intended to contain liquors for drinking.

Arsenic mixed with coaly matter and exposed to the fire becomes violently inflamed and flies off. Advantage has been taken of this property: when it is perceived during the fusion that the glass is coloured yellow for want of calcination, and that the mass is not sufficiently fluid, some manufacturers are in the habit of throwing pieces of arsenic into the pot. The arsenic takes away some of the colour from the glass, and by its inflammation and volatilization gives to the mass an internal movement, which facilitates its settling, and partly clears it of bubbles. But it is evident that it is useful only as a remedy for preceding negligence. Mr. Løysel is of opinion that arsenic may and ought to be banished from the glass-house.

*Concerning Saline Fluxes.*

The pot-ash and soda employed as saline fluxes vary considerably by the quantity of earth and neutral salt they contain. For common glasses the mere ashes  
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are frequently used. In all cases trial is made in the small way of the best proportions of the sand and the alkali.

The neutral salts which are mixed with the alkali are not only hurtful because they diminish the proportion of this last, but principally because they are incapable of combining with vitrifiable earth, and when mixed through the whole mass of the glass, they form a foreign opaque matter. In this state the most active and long-continued heat would be scarcely sufficient to dissipate these salts. The most effectual remedy hitherto discovered consists in diminishing the heat of the furnace when the time of complete fusion is past. The neutral salts being specifically lighter rise to the surface, where they are taken off, and form what is called sandiver, salt of glass, or glass gall; but this operation is attended with a loss of time which is of prejudice, and some of the salt may remain in the manufacture. It is usually seen in the form of white flowers resembling flakes of snow. These kinds of glass are brittle, especially when part of the salt of glass is at the surface. It would therefore be a valuable operation to deprive the alkalis of the neutral salts with which they are mixed. Mr. Loyfel avails himself, for the purification of pot-ash, of its property of being much more abundantly soluble in water than the neutral salts it may contain. One hundred pounds of the saturated solution of fixed vegetable alkali contain forty-eight or fifty pounds of alkali; and this solution makes forty-eight or fifty degrees on the areometer of Baumé. If the evaporation be carried on till the solution is concentrated to the fortieth degree, the greatest part of the foreign salts separate, and what remains cannot injure the glass. This method adds very little to the expence, because the best manufacturers are in the practice of dissolving their potash to separate its impurities.

During the fusion the fixed air is disengaged from the alkali, and produces an effervescence which renders it necessary to increase the number of fusions; adding but small quantities of the mixture at a time, in order that the elastic fluid may be at liberty to escape. By this means the time of fusion is prolonged. The inconveniences of this effervescence are avoided by adding, as Mr. Loyfel proposes, an equal weight of lime to the alkali, in the solution made for the last-mentioned purpose. This caustic alkali is very deliquescent; but it may without any inconvenience be employed in the glass-works immediately after its desiccation.

Pure alkali dissolves a quantity of vitrifiable earth, which is more considerable the greater the intensity of the heat: so that the point of saturation depends on this circumstance. Whence it happens that the glass made at different furnaces is more or less alkaline, and consequently more or less subject to decomposition. If the proportion be such, that the alkali in the glass be less than one fourth of its weight, the glass will be very solid; but if the heat made use of be so feeble that the point of saturation cannot be obtained but by the proportion of equal parts of these two ingredients, the glass, though clear and transparent, will be of so loose a composition as to be attacked and dissolved by mere water.

#### *Concerning Lime.*

Calcareous earth renders the glass into which it enters less subject to attract moisture, and less brittle by changes of heat and cold. Its whiteness is not perceptibly altered; but in order to avoid the effervescence produced by the disengagement of fixed air, the common practice is to use lime. This practice is still more advantageous, because the combustible matters of the lime stone are burned by calcination; and the water, which is one of its component parts, is dissipated. This water, together with the fixed air, if volatilized in the furnace of fusion, would facilitate the escape of part of the alkali.

Vegetable

Vegetable earth, such as is obtained by lixiviation of the ashes of vegetables, is used only for the most ordinary glass, because it alters their clear white colour. As it is fusible alone, which lime is not, it might be employed in large doses without fear of impeding the vitrification of the sand and alkali, if there were not cause to fear the destruction of the pots, which it very speedily corrodes. This property makes it necessary to limit its proportion to one pound for every two pounds of sand, and a sufficient quantity of alkali.

The lime demands for its vitrification a greater quantity of alkali than sand does; yet the doses of sand and alkali being determined for the vitrification, a good glass may be obtained by adding a certain quantity of lime. Whence it happens, that with the same quantity of flux a large quantity of glass is afforded, without considering the good qualities the lime communicates. Lime cannot, however, be used but with great moderation, because the glass of which it is a part vitrifies the clay of the pots, of which the preservation is an important object. From this consideration no more than ten or fifteen pounds of lime are added to one hundred pounds of alkali, and two hundred or two hundred and twenty pounds of vitrifiable earth.

There is an easy remedy against the action of the glass containing calcareous earth upon the pots. It consists in adding to the composition of the glass a sufficient quantity of clay to effect a saturation. This is accordingly done in the manufacture of bottles. But as the clay used in the glass-houses always produces a green glass, it cannot be admitted in the composition of the white glass.

A very remarkable effect of calcareous earth, and also of the vegetable earth, in vitrification, is the decomposition of the vitriolic salts with bases of fixed alkali, whatever may be the manner of their favouring the disengagement of the acid. Calcareous earth may be vitrified in the proportion of one part of the earth to three or four of salt, according to the degree of the fire. This property renders the use of lime and the vegetable earth very advantageous in the manufactories of common glasses, wherein the soda of varec is used, which contains a considerable proportion of Glauber's salt or vitriolated soda.

*Concerning the Substances proper to purify the Glass.*

The substances most advantageously employed in the purification of glass are the calx of arsenic, nitre, and the calx of manganese. The first has been already mentioned.

Nitre serves as a flux by virtue of its alkaline part, and may supply the place of alkali according to the proportion it contains; but its high price prevents its being employed for that purpose. It is with a view to destroy the coaly matters contained in the mixture that it is added, and accordingly it is never used but when the materials have not been enough calcined.

It is likewise with the same view that the calx of manganese is used. We are indebted to Scheele for a knowledge of the manner in which this calx operates. Naturally it gives a violet red colour to glass; but when deprived of part of its oxigene or vital air by the combustion of coaly matter, it loses its colour and leaves the glass white. Hence a notion may be formed of its effects when added to glass in different proportions. If the dose be too small, it does not destroy entirely the yellow colour produced by the coal of the ingredients not sufficiently calcined; if it be too large, it communicates its own peculiar tinge.

The calx of manganese is capable of destroying such colours only as are produced by coaly matter, but not that which arises from metallic substances, such

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as iron, lead, and cobalt. In these cases it produces a mixed colour from the combination of its own tinge and that of the metal already in the glass.

If it be proposed to communicate to glass the colour of the calx of manganese, the materials must be well calcined; and arsenic must not be used, as it would attract the vital air of the calx. Nitre will restore the colour if destroyed. It effects this by affording vital air.

In some cases, when it is desirable to give a slight green tinge to glass, instead of the yellow colour produced by a metallic calx, a small quantity of the calx of cobalt is added, which gives a blue colour, and this by mixture with the yellow produces a green.

The calx of manganese forms a glass specifically heavier than common glass; whence it arises that the glass at the bottom of the pots in many glass works is violet. It is undoubted that when this happens the dose of manganese is too great. The usual method of remedying this inconvenience is to stir up the glass with an iron bar, after previously raising the fire to render it more fluid. It is thought that the manganese is in part dissipated by that means; but it is merely distributed through the mass. A more effectual remedy is to add some combustible substance to the glass to destroy its colour; such as arsenic, charcoal, sulphur, &c.

*Concerning the Calcination of the Vitriifiable Matters.*

The calcination is an important preparation of the materials intended to be vitrified. Its chief effects are the dissipation of volatile substances, which ought not to enter as constituent parts of the glass, and the combustion of coaly matters, which without this operation never fail to colour the glass.

Two conditions are requisite to a perfect calcination: 1. the materials must present a large surface to the air; and 2. the heat to which they are exposed ought not to be attended with the smoke of the fuel. The first condition demands that the heat should not be so violent as to produce fusion. And moreover the heat should be gradually raised, to drive off the volatile matters, without raising along with them any part of those which are more fixed.

The sand made use of is commonly more or less white in its natural state; but it becomes still more so by calcination, and the glass is improved in consequence. The fire may be urged to the strongest degree when sand is calcined by itself; but a moderate heat is commonly used, unless when the very finest glass is intended to be made. In general the sand is subjected to no other calcination than that of the mixture of alkali, lime, &c. called the frit.

The calcination of the alkali is of the first importance. By this means the elastic fluid is driven off which would disturb the fusion. Part of the evaporation of the salt, which takes place before it acts as a solvent to the sand, is thus prevented. And more particularly the coaly matters are burned, which it always retains notwithstanding any other previous depuration.

In the purification of alkalis all such vessels are to be avoided as might communicate colouring particles to them; such as boilers of iron. Those of lead are preferable; because if any portions of the metal should be detached, no sensible inconvenience will arise as to the whiteness of the glass.

The heat must be more particularly attended to in the purification of the alkali, that it may be so moderate as not to produce that liquefaction which is called the aqueous fusion, and arises from the water it contains. For this purpose the salt must be frequently turned, and not calcined in too great a quantity at a time.

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The calcined fixed alkali may be preserved in its concrete form in apartments defended from moisture. The same precaution is not required for the lime and sand.

After the mixture of these three substances the mixture may be subjected to vitrification in the pots of the furnace of fusion; or it may be subjected to another calcination called the operation of the frit. If the mixture of vitrifiable matters be not subjected to this operation, the other ingredients are likewise added at this period, whether they be nitre, arsenic, or calx of manganese, for purifying the glass, or such metallic calces as are intended to produce colour. But if the mixture be fritted, no other materials are now added but the calces which are intended to possess the last state of calcination.

*Concerning the Operation of the Frit.*

The operation of the frit answers two purposes. The first is to complete the combustion of the coaly matter and the dissipation of volatile substances; the second, to incorporate the materials with each other by a beginning of that combination which is perfected in the furnace of fusion.

When a mixture of very dry concrete alkali and sand is made, and immediately subjected to an heat sufficient for its vitrification, the alkali speedily enters into fusion; the sand being more heavy than this fluid alkali, falls to the bottom of the vessel, and the supernatant alkali is in part evaporated before the whole of the sand can be dissolved. In this case the glass will contain unvitrified sand, notwithstanding a sufficient or even superabundant proportion of alkali may have been used. This inconvenience is but too common in those works where the operation of the frit is not used; but it is avoided by that commencement of union which the sand, lime, and alkali acquire in this operation, and which holds them together till the vitrification is completed.

The accurate mixture of the vitrifiable matters can alone produce the clearest glass, which is the properest to receive the several colours afforded by the metallic calces. The frit is therefore an operation of advantage for coloured glasses, as it prevents the production of false or irregular tinges.

Vitrifiable matters newly fritted destroy and corrode the crucibles less than such as have not been so treated: 1. because they are exempt from humidity: and 2. because the alkali is no longer in a disengaged state.

When it is proposed to augment the density of a glass by means of a metallic calx or glass, such as those of lead, the glass produced will be more uniform in its texture, the more equally the combination has been effected through the whole of the mass. Now the commencement of combination, which is established between all the parts of the frit, prevents the calx of lead from falling down as readily as it would otherwise do.

The operation of fritting is performed in one or more furnaces adjacent to the furnace of fusion which communicates with it, and to which the name of *arches à fritte* is given by the French, or otherwise it is done in separate furnaces. The former method is preferable, because the flame does not arrive at the frit until all the parts of the fuel have had time to be consumed; because they can more easily be kept at a steady and suitable heat without an additional expence of fuel, and because the vitrifiable matters may be immediately transferred in their white heat to the furnace of fusion. Hence the vitrification is more speedy, and the crucibles less injured, than if the materials were put in cold.



*Concerning the Fusion of the vitrifiable Matters.*

It is necessary to diminish the heat of the furnace at the time of working the glass, in order that it may assume consistence enough to be wrought; but as the ingredients required to be added from time to time occasion a refrigeration, the furnace is again heated before they are introduced. The time of re-heating differs in different works: but it is ordinarily one or two hours for furnaces of six or seven feet in diameter.

The cold produced by this circumstance being in proportion to the quantity added, it is clearly requisite not to add too much at a time; because too much cooling might even break the vessels. The pots are therefore filled at two, three, or four different intervals; and this is called making two, three, or four fonts (*fontes*).

The second font must not succeed the first until the preceding vitrification is completed. Two methods are used to ascertain this. The first consists in observing the end of the effervescence, and the dissipation of the alkali superabundant to the vitrification; which may be known by the tranquillity of the font. The second consists in taking proof of the glass, after the cessation of the fumes arising from the evaporation of the alkali. If it be found that the bubbles are dissipated, the second font may be made: and the same observation applies to the succeeding fonts.

The time employed in the vitrification is distinguished by the name of the time of fonding, and that employed in the dissipation of the bubbles, the settling or refining (*affinage*). The glass is said to be fine, or well refined, when it contains no more bubbles. If the second font were to be made before the glass of the first were well refined, the subsequent cooling would prevent the dissipation of the bubbles, at least during the whole time requisite to produce the original fluidity, and the subsequent refining would prove long and tedious. While the pots are thus supplied, the vents of the flame must necessarily be kept open, which cools the furnace also. For these reasons, it is proper to avoid either too few, or too many fonts.

As soon as the glass is fine, the heat of the furnace is diminished by adding less fuel, or none at all, according to the nature of the work, whether of blown or of cast glass. By the diminution of heat, the glass becomes thicker or less fluid, and is fit for working. During the whole time of working the consistence must be the same; and for this reason, in the operation of blowing, of which the working may continue from five hours to twenty or more, according to the nature of the articles, the furnace must be kept at the same degree. But this need not be as intense as for the fonding and refining.

This last remark does not quite agree with the account given by Mr. Wedgwood (*Art. Pyrometer*, p. 748) of the fonding, settling and working heats. But I suppose the working heat to be, as Mr. Loyel informs us, lower than the others for blown glass; and that Mr. Wedgwood's increased heat for working may be used only in the manufacture of *cast* plate glass.

There are two methods in practice of conducting the fonding, refining, and working of glass. In the first, each operation is made at the same time in all the pots; in the second, the fonding and refining are effected in one half of the pots, while the glass is worked in the others. It is easy to imagine that the glass works where this last practice prevails cannot have so intense a fire as the others. To supply this defect, a greater quantity of flux is used in the vitrification; and the glass, containing less earth, is tender, and subject to be decomposed. Ex-ception

ception must however be made with regard to those glass works in which no other materials are used but old glass, or very fusible matters, such as lavas, basaltes, &c.

*Of the Annealing of Glass.*

Glasses of any considerable thickness, as for example two or three lines, if suffered to cool in the open air immediately after being formed, suffer an unequal contraction from their surface on account of the inequality of their thickness. These glasses frequently break of themselves by change of temperature. They fly or break with some noise, when an attempt is made to cut them with the diamond, or to grind them on the wheel or other tool. The annealing is a remedy for this defect. It consists in passing the glass, slowly and by insensible degrees, from the state of ignition it possesses in the furnace of fusion to the temperature of the atmosphere. For this purpose, as soon as the work is finished, and has assumed consistence enough to retain its form, it is conveyed, while still at a red heat, into a furnace which has nearly the same heat as itself. There the cooling is effected in one of the two following ways: The annealing furnace is filled with the manufactured articles, and kept at the same heat during the whole time of working, after which it is suffered to cool slowly together with its contents; or otherwise, one or several pieces newly made are gradually passed along the annealing furnace by occasionally removing them from one end, which is hottest, to the other, where it is so low that the pieces may thence be safely transferred into the open air.

The slowness of annealing varies according to the brittleness of the kind of glass, and the thickness of the work. Thus a glass made with flint and alkali alone is more difficult to anneal than if it contained a metallic calx or lime, and the first kind will always be more subject to break by alternations of heat and cold. The vessels to be annealed must be cool enough not to adhere to the support on which they are placed; for the inequality of contraction between them and the support might occasion them to break. The same accident arrives to pieces made of glasses of different dispositions to contract. The contraction of the piece to be annealed is effected more easily, the less friction it has to overcome; for which reason, when large plates of glass are to be annealed, the surface is placed on moveable bodies, such as grains of sand.

*Concerning the principal Defects observable in Works made of Glass.*

The most considerable defects, as enumerated by Mr. Løysel, are striae or veins, threads, tears, cords, bubbles, and knots.

The striae or veins arise from the heterogeneous composition of the glass. It seldom happens that glasses of any considerable magnitude are exempt from them, and the reason is not difficult to explain.

Glass produced by the solution of siliceous earth by fixed alkali, at the ordinary heat of the glass-house, possesses a specific gravity of twenty-three or twenty-four, water being assumed as usual at ten. Glass made with alkali and the clay commonly used weighs about twenty-five. That of alkali and chalk, twenty-seven or twenty-eight. The calx of manganese vitrified alone weighs thirty-two or thirty-three. Glasses produced by other metallic calces are still more ponderous: that of lead, for example, weighs about seventy-two or seventy-three. When the partial combinations of the ingredients of the glass are not well mixed together, but form strata of different density in the pots, they produce undulated veins in the work similar to those observed when two liquids of very different densities are first mixed, such as water and ardent spirit.



As the glass in the operations of blowing is taken up nearly from the same part of the pot, and as in the casting of glass the pot is suddenly reversed and its whole contents mixed together, it is found that blown glass is much more uniform than that which has been cast.

The name of threads is particularly given to those veins which are produced by the vitrification of clay. They are greener than those produced by calcareous earth. These threads render the glass very brittle, when they are abundant, or when any of them are of considerable size, because the contraction and dilatation of this kind of glass from change of temperature, are very different from those of the glass of sand and flint.

Tears are the greatest defect which can be found in glass. They are the drops of glass afforded by the vitrification of the furnace of fusion. Works in which these are found, are brittle. Most of them break by the alternations of temperature, and that the more surely, the nearer the tear is to the surface. Such articles are generally thrown aside in the glass-house.

Cords are asperities on the surface of certain articles of blown glass. They are produced whenever the heat of the furnace becomes so low, that the threads of glass which fall from the pipe into the crucible, cannot resume the proper degree of fluidity. When this appearance presents itself, the work is given up till the heat of the furnace is again brought to the requisite degree.

The small bubbles abundantly diffused through certain glasses shew that the refining is imperfect. They arise from the disengagement of elastic fluid during the vitrification. This imperfection shews either that the quantity of flux has been too small, or the fire too weak. In the first case, the glass may be used to hold liquids without fear of being attacked; in the second, the glass is tender and easily acted on by acids, if the flux were of an alkaline nature, because its proportion is too great.

Bubbles may also be produced in glass, during the working, by certain foreign matters which are fixed, and emit aerial fluid by the heat.

Knots are of three kinds. They are either formed by grains of sand enveloped in the glass, or by the salt of glass which is found in pieces, or white flocks, or lastly by pieces detached from the crucible or the sides of the furnace.

**SILK** \* is a fibre or thread spun by the silk-worm to form a nidus for its preservation in the chrysalis state. It is wound off in the manufactories, and afterwards joined or spun into thicker threads. We do not possess any explanation of the process by which silk, which in the body of the insect has the form of a glutinous unorganized mass, becomes consistent, firm, and very strong, in an exceedingly short time after it has been drawn out into thread. Anglers have a practice of cutting the body of a silk-worm, and drawing out the whole of the silky contents into a string of a few inches long, which speedily acquires consistence, has the appearance of cat-gut or fiddle-string, but is more transparent, and is on that account less visible under water when used as a fishing-line. M. Chappe has made very interesting researches as to the management of this matter. He dissects the vessels out of the silk-worm, washes them with water, and then dilutes their contents by trituration with about one third of its weight of water. By this preparation, they could be blown into permanent globes, and otherwise formed. See *Annales de Chimie*, xi. 113.

Silk appears to be a sort of dried gummy matter. It differs from vegetable sub-

\* Chiefly from Berthollet.

stances, 1. in affording volatile alkali by distillation: 2. in affording azotic gas by treatment with nitrous acid: 3. in affording a peculiar oil, which is separated from it when the nitrous acid converts it into acid of sugar, as has been shewn by Berthollet. It seems to be a compound, consisting of a vegetable mucilage, with a peculiar animal oil which renders it pliant, ductile, and elastic.

Silk is naturally coated with a substance which has been considered as a gum, to which it owes its stiffness and elasticity; that which is most commonly met with in France contains, besides, a yellow colouring matter.

Most of the purposes for which silk is employed require that it should be deprived not only of its colouring matter but also of its gum. Both these purposes are answered by means of soap, and the term scouring (*décreusage*) is applied to this operation, by which it acquires its suppleness and whiteness. The scouring ought not to be so complete for silks which are to be dyed, as for those which are intended to remain white; and a difference ought even to be made, according to the colour we mean the silk should have.

This difference consists chiefly in the quantity of soap employed: thus, for common colours, it is generally thought sufficient to boil the silk for three or four hours in a solution of twenty pounds of soap for each hundred of silk, taking care to fill up the kettle with water from time to time, that there may be always a sufficient proportion of fluid. The quantity of soap is increased for those silks which are to be dyed blue, and more especially for those that are to be scarlet, cherry-colour, &c. because for these colours the ground must be whiter than for such as are less delicate. In treating of each colour, the quantity of soap proper for the silk intended to receive it is mentioned.

When silk is to be employed white, it undergoes three operations. The first is called by the French *dégommage*, and by our workmen *shaking over*; it consists in keeping the hanks of silk in a solution of thirty pounds of soap to a hundred of silk: this solution ought to be very hot, but not boiling: when that part of the hanks which is immersed is entirely freed from its gum, which is known by the whiteness it acquires, the hanks are turned upon the skein sticks, so that the part which was not before immersed may undergo the same operation: they are then taken out of the kettle and wrung out, according as the operation is completed.

The second operation is the *cuite* or boiling. The silk is put into bags of coarse cloth, five-and-twenty or thirty pounds in each bag, which is called a boiling bag (*poche*): a bath of soap is prepared like the former, but with a less quantity of soap; in this the bags are boiled for an hour and a half, taking care to keep them constantly stirred, that those which touch the bottom of the kettle may not receive too much heat.

The third operation is called bleaching or whitening, which is principally intended to give the silk a slight cast, to make the white more pleasing; and from which it derives different names, such as china white, silver white, azure white, or thread white. A solution of soap is prepared, the proper strength for which is determined by its mode of frothing when agitated: for the china white, which should have a slight tinge of red, a small quantity of anotto is added, and the silk is shaken over in it until it has acquired the desired shade. To the other whites, more or less of a blue tinge is given by adding a little blue to the solution of soap, though some had before been put into the *cuite*.

To prepare the azure, fine indigo is taken; and after being well washed two or three



three times in moderately warm water, it is ground fine in a mortar, and boiling water poured on it; it is then left to settle, and the liquor alone is employed, which retains only the most subtile parts: this is called azure. A small quantity of the liquor of a fresh vat of indigo may be substituted for azure.

At Lyons, where they make a more beautiful white than at Paris, no soap is used in the third operation; but after the second, the silks are washed, fumigated with sulphur, and azured with river water. In this method it is of importance to employ very clear water.

When the silk has become very uniform, and has acquired the desired shade, it is wrung out and dried.

The white obtained by these means is not yet sufficiently bright for the silk intended for white stuffs; but must still be exposed to the vapour of sulphur.

As soap seems to impair the lustre of silk, the academy of Lyons, in 1761, proposed as the subject of a prize-dissertation to find a method of scouring silks without soap; and the prize was adjudged to Mr. Rigaut, of S. Quentin, who proposed substituting for soap a solution of soda, or carbonat of soda, so much diluted with water as not to injure the silk; but some inconvenience must have attended the practice of this method, as it is not adopted, though generally known and easy of execution.

The Abbé Collomb\* has published some observations highly worthy of attention, respecting the scouring of silk by the action of water alone. Having perceived that a skein of yellow silk, which he had boiled for about three hours in common water, had lost nearly one eighth of its weight, he repeated the boiling twice, and thereby brought the diminution to nearly one quarter.

The silk which has suffered this loss of weight still retains a yellow or rather charmois colour, which renders it unfit for white stuffs, or for such as are intended to receive any colour the beauty of which depends on the whiteness of the ground upon which it is applied; but it takes those colours very well which cannot be injured by the tinge it retains; thus the black which it took seemed preferable to that of silk scoured with soap.

The silk remains very firm and strong after this operation; the threads of it, compared with similar ones scoured with soap, supported weights which broke the others.

Eight hours of brisk ebullition are required to dissolve the whole gummy coat of silk, and it thereby loses a little more than one fourth of its weight, but the boiling ought to be continued longer when the barometer is low, because the greater the weight of the atmosphere, the higher is the degree of heat at which water boils.

This consideration led M. Collomb to try the effect of boiling silk in Papin's digester, and he found that only one hour and a quarter were required, to complete the solution of the gummy coat, although the degree of heat must have been inferior to that which produced many of those effects observed by philosophers, in that concentrated kind of ebullition.

Berthollet says that he saw a pattern of silk stuff scoured by M. Collomb; it seemed to have the qualities which he mentions; but it had less suppleness and softness than silk scoured with soap.

M. Le Camus, a learned naturalist of the academy of Lyons, gave Berthollet a small quantity of the substance separated from silk by the water, in one of M.

\* Observations sur la Dissolution du Vernis de la Soie. Journ. de Phys. Août, 1785.

Collomb's operations; it was black, brittle, and of a shining fracture, and afforded by distillation the usual products of animal substances; it dissolved easily in warm water, and left very little residuum on the filtre; the solution, which is transparent, and of a greenish yellow colour, was not sensibly affected by acids or alkalis.

Solution of alum produced in it a dirty white precipitate: that of copper, a dark brown precipitate; that of sulphat of iron, a brown precipitate; solution of tin in aqua regia, a white precipitate; acetite of lead, a brown precipitate. All these precipitates are in small quantity, and more or less viscous. The infusion of galls and that of sumach produce a white precipitate.

Alcohol does not dissolve this substance even by ebullition, taking up only a yellow colouring matter; this solution, by evaporation, afforded a residuum of scales of an amber yellow.

Berthollet added some drops of muriatic acid to nearly two ounces of alcohol, and boiled it on twenty grains of the silk gum: a solution took place; but, on cooling, this substance put on the appearance of jelly.

The substance taken from the silk in the scouring, then, appears to be of an animal nature, and therefore the soap-suds used in that operation soon become putrid; when separated from the silk, it is easily dissolved in water, but not in alcohol. Though not of a vegetable nature, it may with considerable propriety be called a gum. That part which gives it the yellow colour is soluble in alcohol, and when it is separated the gum becomes brown. It is not improbable that this colour is occasioned by the heat to which it is exposed in the boiling, because when only the yellow colouring part is separated by M. Baumé's process, which will presently be described, the silk is whitened.

In M. Collomb's process the gum is separated, and takes with it only some of the colouring particles; and in the process of scouring by soap the gum and the yellow colouring particles are carried off together.

Berthollet boiled some yellow silk in a retort, where, as the vapours did not escape so freely as from an open vessel, a degree of heat must have been produced superior to that of water boiling in the open air. After having been boiled for four hours, the silk had lost one fourth of its weight, but it had almost entirely retained its colour.

The same chemist boiled another pattern in the same way, in a quantity of water impregnated with common salt; it became whiter, but lost less of its weight, though the degree of heat was certainly increased by the addition of the salt, which restrained the evaporation of the water: possibly a part of the salt had united with the silk. Experiments might be made with other salts; and perhaps we should find some, that, without injuring the silk, might be more useful in dissolving the gum and colouring particles.

When the silk is intended for the manufacture of blonds and gauzes, its natural elasticity and stiffness should be preserved: the greatest part of what is produced in France is of a yellow colour, but it is the white China silk that is principally used for these purposes; this is so dear, that the French manufacturers cannot vie with the English, from whom they get it, as the English always reserve the finest for their own manufactures. It has therefore been a desideratum to find out the means of depriving the yellow silk of its colouring particles, without destroying the gum, and thereby depriving the silk of its elasticity. M. Baumé has solved this interesting problem, but has kept his process secret: some artists, however, to whom he had entrusted it, or who had been led to the discovery by their own observations, succeeded in the execution of it; but the process appears to be

liable



liable to accidents, which by occasioning loss increase expence ; so that hitherto, notwithstanding the advantages it presents, it has not been carried into execution. The following is an account of what has transpired respecting it :

A mixture is made with a small quantity of marine acid and alcohol, in which the silk is immersed ; the marine acid must be pure, and not contain any nitrous acid, which makes the silk yellow. To give it an uniform white colour seems to be one of the most difficult parts of the process, especially when the operation takes place on large quantities. There is likewise great difficulty in dyeing the whitened silk, so as to prevent its curling ; it ought certainly to be kept constantly stretched during the drying. The alcohol that has been impregnated with the colouring part must be again separated from it, so as to serve for subsequent operations, otherwise the process would be too expensive ; for this purpose it is to be distilled by a gentle heat, in a glass or stone-ware vessel.

It appears from the experiments above related, that the marine acid is useful in this process, by softening the gum, and thus assisting the alcohol to dissolve the colouring particles combined with it.

The preparation with alum must be considered as one of the general operations in dyeing silk ; for without aluming, the greatest part of the colours applied would possess neither beauty nor durability.

The preparation with alum consists in mixing in a tun or vat, about forty or fifty pails of water with forty or fifty pounds of Roman alum, that has been previously dissolved in warm water ; this must be carefully stirred during the mixture, to prevent the crystallization of the alum.

After having washed and bathed the silk, and wrung it out with the jack and pin\*, in order to separate any soap it may have retained, it is immersed in the alum liquor, where it is left for eight or nine hours ; after which it is wrung out by hand over the vat, and washed in a stream of water.

In the above quantity of liquor one hundred and fifty pounds of silk may be prepared, without the addition of any more alum ; but when it begins to grow weak, which those who are in the habit of employing it can easily distinguish by the taste, twenty or twenty-five pounds of dissolved alum must be added as before, and this addition must be repeated until the liquor acquires a disagreeable smell ; and then it may be employed in the preparation of stuffs intended for darker colours, such as browns and marones, till it has lost all its strength.

The preparation of silk with alum is always made in the cold, because when the liquor is employed hot the lustre of the silk is liable to be impaired.

**SILVER** is the whitest of all metals, considerably harder than gold, very ductile and malleable, but less malleable than gold ; for the continuity of its parts begins to break when it is hammered out into leaves of about the hundred and sixty thousandth of an inch thick, which is more than one third thicker than gold leaf : in this state it does not transmit the light. Its specific gravity is moderate, being inferior to platina, gold, mercury, and lead. It ignites before melting, and requires a strong heat to fuse it. The heat of common furnaces is insufficient to calcine it : but the heat of the most powerful burning lenses vitrifies a portion of it, and causes it to emit fumes ; which, when received on a plate of gold, are found

\* This is a contrivance for wringing more strongly than can be done by the hands alone ; the pin introduced through the hank at one end, or into a twist of the cloth, is secured in a fixed position, while the other end or twist is fixed to the hook of the jack, which can be forcibly turned round by means of a winch connected with it. When this degree of force is not necessary, and the hands only are employed in the operation, it is called wringing out by hand.



to be silver in the metallic state. It has likewise been partly calcined by twenty successive exposures to the heat of the porcelain furnace at Séves. The air alters it very little: though it is disposed to obtain a thin purple or black coating from the sulphureous vapours which are emitted from animal substances, drains, or putrefying matters. This coating, after a long series of years, has been observed to scale off from images of silver exposed in churches; and was found, on examination, to consist of silver united with sulphur.

Silver is soluble in the vitriolic acid when concentrated and boiling, and the metal in a state of division. The marine acid scarcely acts upon it, unless dephlogisticated: but the nitrous acid dissolves it with great rapidity, and with a plentiful disengagement of nitrous air; which, during its extrication, gives a blue or green colour to the acid, that entirely disappears if the silver made use of be pure; if it contain copper, the solution remains greenish; and if the acid contain either vitriolic or marine acid, these combine with a portion of the silver, and form scarcely soluble compounds, which fall to the bottom. If the silver contain gold, this metal separates in blackish coloured flocks. The nitrous acid dissolves more than half its weight of silver; and the solution is very caustic, that is to say, it destroys and corrodes animal substances very powerfully. This action appears to depend on the strong disposition of the silver to become revived; by which it either attracts phlogiston from those substances according to the ancient theory, or communicates vital air to them according to the new theory; so that the animal substances undergo a process equivalent to combustion.

The solution of silver, when fully saturated, deposits thin crystals as it cools, and also by evaporation. These are called lunar nitre, or nitre of silver. A gentle heat is sufficient to fuse them, and drive off their water of crystallization. In this situation it is of a black colour, may be cast into small sticks in a mould, and then forms the lapis infernalis, or lunar caustic, used in surgery. A stronger heat decomposes lunar nitre, the acid flying off, and the silver remaining pure. It is obvious that, for the purpose of forming the lunar caustic, it is not necessary to suffer the salt to crystallize, but that it may be made by evaporating the solution of silver at once to dryness; and as soon as the salt is fused, and ceases to boil, it may be poured out. The nitrous acid driven off from lunar nitre is decomposed, the products being vital air and phlogisticated air.

Although the nitrous acid dissolves silver with such great facility, it appears to do this only in consequence of its great power to calcine the metal: for the vitriolic and marine acids have a greater attraction for the calx. They accordingly take it from that acid, and form salts; which, as we have already observed, fall to the bottom on account of their difficult solubility. The vitriol of silver, which is formed by pouring vitriolic acid into the nitrous solution of silver, is sparingly soluble in water; and on that account forms crystals, which are so small that they compose a white powder. The marine acid precipitates from nitrous acid the saline compound called luna cornea, or horn silver; which has been so distinguished because, when melted and cooled, it forms a semi-transparent and partly flexible mass, resembling horn. It is supposed that a preparation of this kind has given rise to the accounts of malleable glass.

If any salt with base of alkali, containing the marine acid, be added to the nitrous solution of silver, the same effect takes place by double affinity; the alkaline base uniting with the nitrous acid, and the silver falling down in combination with the marine acid.

Since the marine acid throws down only silver, lead, and mercury, and the latter



of these two is not present in silver that has passed cupellation, though a small quantity of copper may elude the scorification in that process, the silver which may be revived from luna cornea is purer than can readily be obtained by any other means. When this salt is exposed to a low red heat, its acid is not expelled; and a greater heat causes the whole concrete either to rise in fumes, or to pass through the pores of the vessel. To reduce it, therefore, it is necessary that it should be triturated with its own weight of fixed alkali, and a little water, and the whole afterwards exposed to heat in a crucible whose bottom is covered with mineral alkali; the mass of luna cornea being likewise covered with the same substance. In this way the acid will be separated from the silver, which is reduced to its metallic state.

As the precipitate of luna cornea is very perceptible, the nitrous solution of silver is used as a test of the presence of marine acid in waters; for a drop of this solution poured into such waters will cause a very evident cloudiness. The solution of silver is also used by assayers to purify the nitrous acid from any admixture of marine acid. In this state they call it precipitated aqua fortis.

The precipitates of silver which are formed by the addition of alkalis or earths are all reducible by mere heat, without the addition of any combustible substance. The fulminating combination of volatile alkali with silver, exhibits one of the most astonishing instances of chemical detonation hitherto known\*. Pure silver is dissolved in pale nitrous acid, and precipitated by the addition of lime water. This calx or precipitate, after decantation of the fluid, is to be dried by exposure to the air for three days. The inventor thinks the presence of light has some influence in the success of the experiment. The dried calx being agitated or stirred in a solution of caustic volatile alkali, assumes the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air. This is the fulminating silver.

Gunpowder and fulminating gold are not to be compared with this new product; as the former requires ignition, and the latter a sensible degree of heat, to cause them to fulminate. But the slightest agitation or friction is sufficient to cause the fulminating silver to explode. When it is once obtained, it can no more be touched. The falling of a few atoms of this preparation from a small height produced the detonation; a drop of water falling on it had the same effect. No attempts therefore can be made to inclose it in a bottle; but it must remain in the capsule wherein, by evaporation, it obtained this terrible property.

To make this experiment with safety, it is proper to use no greater quantity than a grain of silver; the last desiccation should be made in a metallic vessel; and the face of the operator should be defended by a mask, with holes for the eyes defended with strong glass.

The volatile alkali made use of in converting the calx of silver into the black precipitate, was exposed to ebullition in a small matrafs of glass; and the fluid being then suffered to cool, the inside of the vessel became lined with small crystals. When one of these was touched beneath the cold liquor, an explosion took place, which broke the matrafs in pieces, and threw the liquid up to the ceiling of the laboratory.

The inventor's theory of these effects is the same as that of fulminating gold. The combination consists of volatile alkali and calx of silver; that is to say, in

\* Discovered by Berthollet. See the Journal de Physique for June 1788, p. 474.

the new theory, of inflammable air, phlogisticated air, silver, and vital air. The slightest change of temperature or agitation disposes the inflammable air to combine with the vital air, which adheres very feebly to the silver. These form water, while the phlogisticated air is disengaged, and the silver reduced to the metallic state. The explosion depends on the sudden transition of the phlogisticated air and the water to the elastic state by heat: but the change of capacity from which the heat arises has not yet been explained. On the phlogistic theory, it will be said, that the silver is revived by combining with the inflammable air, or phlogiston of the alkali; while the phlogisticated and vital air fly off in the explosion.

Chemists have long been acquainted with the compound acid called aqua regia, from its action being exerted on few of the metals except gold. But the discovery of a compound acid acting still more exclusively upon silver, is due to one of our contemporaries Mr. Keir. The effects of aqua regia have been described, considered and explained by a great variety of authors. Those of Mr. Keir's compound acid are confined to the Philosophical Transactions, a work which, though its circulation extends to every part of the globe, is comparatively speaking confined to few hands. For this reason, it appears proper to give an ample account of the experiments of this chemist.

Mr. Keir's paper\* consists of two parts: the first shews the effects of compounding the vitriolic and nitrous acids in dissolving metals, and the other describing some curious appearances which occur in the precipitation of silver, from its solution in nitrous acid by iron, and by some other substances.

#### PART I. SECTION I.

##### *Effects of compounding the vitriolic and nitrous Acids upon the Dissolution of Metals†.*

No two substances, says the author, are more frequently in the hands of chemists and artists than vitriolic acid and nitre; yet, he says, he has found that a mere mixture of these, when much concentrated, possesses properties which neither the vitriolic nor nitrous acid, of the same degree of concentration, have singly, and which could not easily be deduced a priori, by reasoning from our present knowledge of the theory of chemistry.

Having found by some previous trials, that a mixture composed of nitre, dissolved in oil of vitriol, was capable of dissolving silver easily and copiously, while it did not affect copper, iron, lead, regulus of cobalt, gold and platinum; he conceived that it might be useful in some cases of the parting of silver from copper, and the other metals above mentioned; and having also observed, that the dissolving powers of the mixture of vitriolic and nitrous acids varied greatly in different degrees of concentration and phlogistication, he thought an investigation of these effects might be a subject fit for philosophical chemistry, and might tend to illustrate the theory of the dissolution of metals in acids: with these views he made the following experiments:

#### EXPERIMENT I.

Into a long necked retort, the contents of which, including the neck, were 1400 grain measures, 100 grain measures of oil of vitriol were put, of the usual

\* Philosophical Transactions, 1790. Part 2.

† To prevent any confusion of terms, Mr. Keir confines the word *solution* to express the substance dissolved, together with its solvent, and the word *dissolution* to denote the act of dissolving.



density at which it is prepared in England, i. e. whose specific gravity is to that of water as 1.844 to 1, and 100 grains of pure and clear nitre, which was then dissolved in the acid by the heat of a water bath. To this mixture 100 grains of standard silver were added; the retort was set in a water bath, in which the water was made to boil, and a pneumatic apparatus was applied to catch any air or gas which might be extricated.

The silver began to dissolve, and the solution became of a purple or violet colour. No air was thrown into the inverted jar, excepting a little of the common air of the retort, by means of the expansion which it suffered from the heat of the water-bath, and from some nitrous fumes which appeared in the retort, and which having afterwards condensed, occasioned the water to rise along the neck of the retort, and mix with the solution. The remaining silver was then separated and weighed, and it was found that 39 grains had been dissolved; but probably more would have been dissolved, if the operation had not been interrupted by the water rushing into the retort.

#### EXPERIMENT II.

In the same apparatus, 200 grains of standard silver were added to a mixture of 100 grains of nitre, previously dissolved in 200 grain measures of oil of vitriol; and in this solvent 92 grains of the silver were dissolved, without any production of air or gas. The solution, which was of a violet colour, having been poured out of the retort while warm (for with so large a proportion of nitre, such mixtures, especially after having dissolved silver, are apt to congeal with small degrees of cold), in order to separate the undissolved silver from it, and having been returned into the retort without this silver, 200 grains of water were poured into the retort, upon which a strong effervescence took place between the solution and the water, and 3100 grain measures of nitrous gas were thrown into the inverted jar. Upon pouring 200 grains more of water into the retort, 600 grain measures of the same gas were expelled. Further additions of water yielded no more gas; neither did the silver, when afterwards added to this diluted solution, give any sensible effervescence, or suffer a greater loss of weight than 2 grains.

#### EXPERIMENT III.

In the same apparatus, 100 grains of standard silver were exposed to a mixture of 30 grains of nitre dissolved in 200 grain measures of oil of vitriol: and in this operation 80 grains of silver were dissolved, while at the same time 4500 grain measures of nitrous gas were thrown into the inverted jar. When the undissolved silver was removed, 200 grains of water were added to the solution, which was of a violet colour, and upon the mixture of the two fluids an effervescence happened; but only a few bubbles of nitrous gas were then expelled.

#### EXPERIMENT IV.

In the same apparatus 100 grains of standard silver were exposed to a mixture of 200 grain measures of oil of vitriol, 200 grains of nitre, and 200 grains of water; and in this operation 20 grains of the silver were dissolved without any sensible emission of air or gas.

Mr. Keir remarks that in these experiments the copper contained in the standard silver gave a reddish colour to the saline mass which was formed in the solution, and seemed to be a calx of copper interspersed through the salt of silver.

silver. This was all the difference he could perceive between the effects of pure and standard silver dissolved in this acid.

Tin was next exposed to the same mixture of oil of vitriol and nitre, in the same apparatus, and in the same circumstances, care being always taken to add more metal than could be dissolved, that by weighing the remainder, the quantity capable of being dissolved might be found, as had been done with the experiments on silver: the results were as follow:

#### EXPERIMENT V.

No tin was dissolved nor calcined by the mixture in the proportion of 200 grain measures of oil of vitriol to 200 grains of nitre, nor by another mixture in the proportion of 200 grain measures of oil of vitriol to 150 grains of nitre, and consequently no gas was produced in either instance.

#### EXPERIMENT VI.

With a mixture in the proportion of 200 grain measures of oil of vitriol and 100 grains of nitre, the tin began soon to be acted upon, and to be diffused through the liquor; but no extrication of gas appeared until the digestion had been continued two hours in boiling water, and then it took place, and gave a frothy appearance to the mixture, which was of an opaque white colour, from the powder of tin diffused among it. In this experiment the quantity of tin thus calcined was 73 grains, and the quantity of nitrous gas extricated during this action on the tin, was 8500 grain measures. Then, upon pouring 200 grains of water into the retort, a fresh effervescence took place between the water and the white opaque mass, and 4600 grain measures of nitrous gas were thrown into the inverted receiver.

#### EXPERIMENT VII.

With a mixture in the proportion of 100 grain measures of oil of vitriol to 30 grains of nitre, 30 grains of tin were dissolved or calcined, and the nitrous gas, which began to be extricated much sooner than in the last-mentioned experiment, with a larger proportion of nitre, amounted to 6300 grain measures. Water added to this solution of tin did not produce any effervescence.

#### EXPERIMENT VIII.

With a mixture in the proportion of 200 grain measures of oil of vitriol, 200 grains of nitre, and 200 grains of water, 133 grains of tin were acted on with an effervescence, which took place violently, and produced 6300 grain measures of nitrous gas.

The several mixtures above mentioned, in different proportions of nitre and oil of vitriol, did by the help of the heat of a water-bath calcine mercury into a white or grayish powder. Nickel was also partly calcined and partly dissolved by those mixtures. It was not perceived that any other metal was affected by them, excepting that the surfaces of some of them were tarnished.

These mixtures of oil of vitriol and nitre, the author observes, were apt to congeal by cold, those especially which had a large proportion of nitre. Thus, a mixture of 1000 grain measures of oil of vitriol, and 480 grains of nitre, after having kept fluid several days in a phial not so accurately stopped as to prevent altogether the escape of some white fumes, congealed at the temperature of 55° of Fahrenheit's thermometer; whereas some of the same liquid having been mixed



mixed with equal parts of oil of vitriol, did not congeal with a less cold than 45°. The congelation is promoted by exposure to air, by which white fumes rise, and moisture may be absorbed, or by any other mode of slight dilution with water.

Dilution of this compound acid with more or less water, alters considerably its properties, with regard to its action on metals. Thus, in its concentrated state it does not act on iron; but by adding water, it acquires a power of acting on that metal, and with different effect, according to the proportion of the water added. Thus, by adding to two measures of the compound acid, one measure of water, the liquor is rendered capable of calcining iron, and forming with it a white powder, but without effervescence. With an equal measure of water effervescence was produced. With a larger proportion of water the iron gave also a brown colour to the liquor, such as phlogisticated nitrous acid acquires from iron, or communicates to a solution of martial vitriol in water.

Dilution with water renders this compound acid capable of dissolving copper, zinc, and probably those other metals which are subject to the action of the dilute vitriolic or nitrous acids.

## SECTION II.

### *New Process for separating Silver from Copper.*

The properties of this liquor in dissolving silver easily without acting on copper, have rendered it capable of a very useful application in the arts. Among the manufactures at Birmingham, that of making vessels of silver plated on copper is a very considerable one. On cutting out the rolled plated metal into pieces of the required form and sizes, there are many shreds, or scraps as they are called, unfit for any purpose but the recovery of the metals by separating them from each other. The easiest and most economical method of parting these two metals, so as not to lose either of them, is an object of some consequence to the manufacturers. For this purpose, two modes were practised: one, by melting the whole of the mixed metals with lead, and separating them by eliquation and testing; and the second, by dissolving both metals in oil of vitriol, with the help of heat, and by separating the vitriol of copper, by dissolving it in water, from the vitriol of silver, which is afterwards to be reduced and purified. In the first of these methods, there is a considerable waste of lead and copper; and in the second, the quantity of vitriolic acid employed is very great, as much more is dissipated in the form of volatile vitriolic or sulphureous acid, than remains in the composition of the two vitriols.

Some years ago, the author communicated to an artist the method of effecting the separation of silver and copper, by means of the above-mentioned compound of vitriolic acid and nitre; and as it is now commonly practised by the manufacturers in Birmingham, he thinks it is much more economical, it is certainly much more easily executed, than any of the other methods: for nothing more is required than to put the pieces of plated metal into an earthen glazed pan; to pour upon them some of the acid liquor, which may be in the proportion of eight or ten pounds of oil of vitriol to one pound of nitre; to stir them about, that the surfaces may be frequently exposed to fresh liquor, and to assist the action by a gentle heat from 100° to 200° of Fahrenheit's scale. When the liquor is nearly saturated, the silver is to be precipitated from it by common salt, which forms a luna cornea, easily reducible by melting it in a crucible with a sufficient

sufficient quantity of pot-ash; and, lastly, by refining the melted silver if necessary, with a little nitre thrown upon it. In this manner the silver will be obtained sufficiently pure, and the copper will remain unchanged. Otherwise, the silver may be precipitated in its metallic state, by adding to the solution of silver a few of the pieces of copper, and a sufficient quantity of water to enable the liquor to act upon the copper.

The property which this acid mixture possesses of dissolving silver with great facility, and in considerable quantity, will probably render it an useful menstruum in the separation of silver from other metals; and as the alchemists have distinguished the peculiar solvent of gold under the title of aqua regis, a name sufficiently distinctive, though founded on a fanciful allusion; so, if they had been acquainted with the properties of this compound, they would probably have bestowed on it the appellation of aqua regina.

### SECTION III.

#### *Change of Properties communicated to the Mixture of vitriolic and nitrous Acids by Phlogistication.*

The above-described compound acid may be phlogisticated in different methods, of which the author mentions three.

First. By digesting the compound acid with sulphur, by means of the heat of a water-bath: the liquor dissolves the sulphur with effervescence, loses its property of yielding white fumes; and if the quantity of sulphur be sufficient, and the heat applied be long enough continued, it exhibits red nitrous vapours, and assumes a violet colour.

Secondly. If instead of dissolving nitre in concentrated vitriolic acid, this acid be impregnated with nitrous gas, or with nitrous vapour; by making this gas or vapour pass into the acid, this compound will be phlogisticated, as it contains not the entire nitrous acid, but only its phlogisticated part or element, the nitrous gas, without the proportion of pure air necessary to constitute an acid. This impregnation of oil of vitriol with nitrous gas, or nitrous vapour, was first described, and some of the properties of the impregnated liquor noticed, by Dr. Priestley\*.

Thirdly. By substituting nitrous ammoniac instead of nitre in the mixture with oil of vitriol.

The compound prepared by any of these methods, but especially by the first and second, differs considerably in its properties with regard to its action on metals, from the acid described in the first section. It has been observed that the latter compound has little action on any metals, but silver, tin, mercury, and nickel. On the other hand, the phlogisticated compound not only acts on these, but also on several others. It forms with iron a beautiful rose-coloured solution, without application of any artificial heat; and in time a rose-coloured saline precipitate is deposited, which is soluble in water, with a considerable effervescence. It dissolves copper, and acquires from this metal, and also from regulus of cobalt, zinc, and lead, pretty deep violet tinges. Bismuth, and regulus of antimony, were also attacked by this phlogisticated acid.

To ascertain more exactly the effects of this phlogisticated acid on some metals, the author made the following experiments, with a liquor prepared by making nitrous gas pass through oil of vitriol during a considerable time.

\* See Experiments and Observations on Air, vol. iii. p. 129 and 217.



## EXPERIMENT I.

To 200 grain measures of the oil of vitriol, impregnated with nitrous gas, put into a retort with a long neck, the capacity of which, including the neck, was 1150 grain measures, 144 grains of standard silver were added, and the mouth of the retort was immersed in water, under an inverted jar filled with water, to catch the gas which might be extricated.

The acid began to dissolve the silver with effervescence, without application of heat; the solution became of a violet colour, and the quantity of nitrous gas received in the inverted jar was 14700 grain measures. Upon weighing the silver remaining, the quantity which had been dissolved was found to be 79 grains. When water was added to the solution, an effervescence appeared, but only a very small quantity of gas was extricated. By means of the water, a white saline powder of silver, soluble in a larger quantity of water, was precipitated from the solution. The solution of silver, when saturated and undiluted, congeals readily in cool temperatures; and, when diluted to a certain degree with water, gives foliated crystals.

## EXPERIMENT II.

In the same apparatus, and in the same manner, 100 grain measures of this impregnated oil of vitriol were applied to iron. An effervescence appeared without application of heat, the surface of the iron acquired a beautiful rose-colour, or redness mixed with purple: and this colour gradually pervaded the whole liquor, but disappeared on keeping the retort some time in hot water. Notwithstanding a considerable apparent effervescence, the quantity of air expelled into the inverted jar was only 400 grain measures, of which one quarter was nitrous, and the rest phlogisticated. The solution was then poured out of the retort, and the iron was found to have lost only two grains in weight. The solution was returned into the retort without the iron, and 200 grains of water were added to it; upon which a white powder was immediately precipitated, which re-dissolved with great effervescence. When 2000 grain measures of nitrous gas had been expelled into the inverted jar, without application of heat, the retort was placed in the water-bath, the heat of which rendered the effervescence so strong, that the liquor boiled over the neck of the retort, so that the quantity of gas extricated could not be ascertained.

## EXPERIMENT III.

In the same manner, 11 grains of copper were dissolved in 100 grain measures of impregnated oil of vitriol. The solution was of a deep violet colour, and at last was turbid. The quantity of nitrous gas expelled into the inverted jar, during the operation, was 4700 grain measures. When the copper was removed, and 200 grains of water were added to the solution, an effervescence took place, 1700 grain measures of nitrous gas were expelled, and the solution then acquired a blue colour.

## EXPERIMENT IV.

With the same quantity of impregnated oil of vitriol, tin was reduced in weight 16 grains: the liquor acquired a violet colour, became turbid by the suspension of the calx of tin, and 4100 grain measures of nitrous gas were extricated without heat, and 4900 with heat.

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## EXPERIMENT V.

Mercury treated in the same manner formed a thick turbid liquor, which was rendered clear by adding unimpregnated oil of vitriol. The liquor soon afterwards acquired a purple colour, the mercury sunk to the bottom, in the form of a white powder; and the purple liquor, when a solution of common salt in water was added to it, shewed no signs of containing mercury in a dissolved state.

The nitrous gas with which the oil of vitriol is impregnated shews no disposition to quit the acid by exposure to air; but on adding water, the gas is expelled suddenly with great effervescence, and with red fumes. Thus,

## EXPERIMENT VI.

Upon adding 240 grains of water to 60 grain measures of impregnated oil of vitriol, 2,300 grains of nitrous gas were thrown into the receiver; but as the action of the two liquors is instantaneous, the quantity of gas expelled from the retort before its neck could be immersed in water and placed under the receiver, must have been considerable. The whole of the gas, however, was not extricated by means of the water; for the remaining liquor dissolved five grains of copper, while 800 measures of nitrous gas were thrown into the retort.

From the preceding experiments Mr. Keir deduces the following facts:

1. That a mixture of the vitriolic and nitrous acids in a concentrated state, has a peculiar faculty of dissolving silver copiously.
2. That it acts upon, and principally calcines tin, mercury, and nickel (the latter of which, however, it dissolves in small quantity), and that it has little or no action on other metals.
3. That the quantity of gas produced while the metal is dissolving is greater, relatively to the quantity of metal dissolved, when the proportion of nitre to the vitriolic acid is small, than when it is large; and that when the metals are dissolved by mixtures containing much nitre, and with a small production of gas, the solution itself, or the metallic salt formed in it, yields abundance of gas when mixed with water.
4. That dilution with water renders the concentrated mixture less capable of dissolving silver, but more capable of acting on other metals.
5. That this mixture of highly concentrated vitriolic and nitrous acids acquires a purple or violet colour when phlogisticated, either by addition of inflammable substances, or sulphur, or by its action on metals, or by very strong impregnation of oil of vitriol with nitrous gas\*.
6. That this phlogistication was found to communicate to the mixture the power of dissolving, though in small quantities, copper, iron, zinc, and regulus of cobalt.
7. That water expels from a highly phlogisticated mixture of concentrated vitriolic and nitrous acids, or of oil of vitriol impregnated with nitrous gas, a great part of its contained gas, and that therefore this gas is not capable of being retained in such quantity by dilute as by concentrated acids. Water unites with the mixture of oil of vitriol and nitre, without any considerable effervescence.

\* Mr. Keir observes, that Dr. Priestley has noticed this colour communicated to oil of vitriol by impregnation with nitrous gas or vapour, and also the effervescence produced by adding water. See Experiments and Observations, vol. iii. p. 129 and 217.



To these observations the author subjoins another fact, viz. that when to the mixture of oil of vitriol with nitre a saturated solution of common salt in water is added, a powerful aqua regis is produced, capable of dissolving gold and platinum; and this aqua regis, though composed of liquors perfectly colourless, and free from all metallic matter, acquires at once a bright and deep yellow colour. The addition of dry common salt to the concentrated mixtures of vitriolic and nitrous acids produces an effervescence, but not the yellow colour; for the production of which, therefore, a certain proportion of water seems to be necessary.

## PART II.

### *On the Precipitation of Silver from Nitrous Acid by Iron.*

Mr. Keir introduces his account of the experiments which are the subject of this part of his paper, by remarking, that Bergman\* relates, that upon adding iron to a solution of silver in nitrous acid no precipitation ensued, although the affinity of iron to acids in general is known to be much stronger than that of silver; and although even with regard to the nitrous acid, other experiments evince the superior affinity of iron: for as iron precipitates copper from this acid, and as copper precipitates silver, we must infer, he observes, the greater affinity of iron than that of silver. In the course of Bergman's experiments, however, some instances of precipitation occurred, which he attributed to the peculiar quality of the irons thus employed. With a view to discover the circumstances, and to investigate the cause of this irregularity and exception to the general received laws of affinity, Mr. Keir made the following experiments:

#### EXPERIMENT I.

A piece of fine silver was digested in pure and pale nitrous acid; and while the dissolution was going on, and before the saturation was completed, a portion of the solution was poured upon pieces of clean and newly-scraped iron wire into a wine glass, and a sudden and copious precipitation of silver ensued. The precipitate was at first black, then it assumed the appearance of silver, and was five or six times larger in diameter than the piece of iron wire which it enveloped. The action of the acid on the iron continued some little time, and then it ceased; the silver re-dissolved, the liquor became clear, and the iron remained bright and undisturbed in the solution at the bottom of the wine glass, where it continued during several weeks, without suffering any change, or effecting any precipitation of the silver.

#### EXPERIMENT II.

When the solution of silver was completely saturated, it was no longer affected by iron, according to Bergman's observation.

#### EXPERIMENT III.

Mr. Keir having found that the solution acted on the iron, and was thereby precipitated before it had been saturated, and not afterwards, was desirous of knowing whether the saturation was the circumstance which prevented the action and precipitation. For this purpose he added to a portion of the saturated solution some of the same nitrous acid, of which a part had been employed to

\* *Dissertatio de Phlogist. Quantitate in Metallis.*

dissolve the silver; and into this mixture, abounding with a superfluous acid, the threw a piece of iron, but no precipitation occurred. It was thence evident, that the saturation of the acid was not the only circumstance which prevented the precipitation.

#### EXPERIMENT IV.

To another portion of the saturated solution of silver, some red smoking nitrous acid was added; and upon trial, it was found, that iron precipitated the silver from this mixture, and that the same appearances were exhibited which had been observed with the solution previously to its saturation.

#### EXPERIMENT V.

The same effects were produced when vitriolic acid was added to the saturated solution of silver, and iron afterwards applied.

#### EXPERIMENT VI.

To some of the same nitrous acid, of which a part had been employed to dissolve the silver, a piece of iron was added; and while the iron was dissolving, some of the saturated solution of silver was poured into the liquor; upon which a precipitation of silver took place instantly; although when the same acid had been previously mixed with the solution of silver, and the iron was then added to the mixture, no precipitation had ensued.

#### EXPERIMENT VII.

The quantity of vitriolic acid, or of the red fuming nitrous acid, necessary to communicate to the saturated solution of silver the property of being acted on by iron, varies according to the concentration, and to the degree of phlogistication of the acid added; so that a less quantity than is sufficient does not produce any apparent effect. Nevertheless, when the solution of silver is by addition of these acids brought nearly to a precipitable state, the addition of spirit of wine will, in a little time, render it capable of acting on iron.

It appears then, that a solution of silver is not precipitated by iron in cold, unless it have a superabundance of phlogisticated acid.

#### EXPERIMENT VIII.

Heat affects the action of a solution of silver on iron; for if iron be digested with heat in a perfectly saturated solution of silver, such as a solution of crystals of nitre of silver in water, the silver will be deposited in its bright metallic state on different parts of the iron, and the iron which has been acted on by the solution, appears in form of a yellow ochre.

#### EXPERIMENT IX.

Bergman relates, that he has sometimes observed beautiful crystallizations or vegetations of metallic silver formed on pieces of iron immersed long in a solution of silver. Mr. Keir observes, he has found that no time is able to effect this deposition, unless the solution be in a state nearly sufficiently phlogisticated to admit of a precipitation by iron, but not completely phlogisticated enough to effect that purpose immediately.

#### EXPERIMENT X.

Dilution with a great deal of water seemed to dispose the solutions of silver to be precipitated by iron more easily. A solution of silver, which did not act on



iron, upon being very much diluted, and having a piece of iron immersed in it, during several hours, gave a precipitate of silver in the form of a black powder.

## SECTION II.

*On the Alterations which Iron on its Surface undergoes by the Action of a Solution of Silver in Nitrous Acid, or of a pure concentrated Nitrous Acid.*

It has been said, that when iron is exposed to the action of a phlogisticated solution of silver, it instantly precipitates the silver, is itself acted upon or dissolved by the acid solution, during a certain time, longer or shorter, according to the degree of phlogistication, quantity of superabundant acid, and other circumstances; and that at length the solution of the iron ceases; the silver precipitate is re-dissolved, if there is superfluous acid; the liquor becomes clear again, but only rendered a little browner by its having dissolved some iron; while the piece of iron remains bright and undisturbed at the bottom of the liquor, where it is no longer able to affect the solution of silver.

## EXPERIMENT I.

A part of the phlogisticated solution of silver which had passed through these changes, and which had ceased to act upon the piece of iron, was poured into another glass, and another piece of fresh iron wire was dropped into the liquor, upon which a precipitation of the silver ensued, a solution of part of the iron, a re-dissolution of the precipitated silver, and a cessation of all those phenomena, with the iron remaining bright and quiet at the bottom of the liquor, as before. It appeared then, that the liquor had not lost its power of acting on fresh iron, although it ceased to act on that piece which had been exposed to it.

## EXPERIMENT II.

To one of the pieces of iron which had been employed in the precipitation of a solution of silver, and from which the solution no longer capable of acting upon it had been poured off, some phlogisticated solution of silver was added, which had never been exposed to the action of iron, but no precipitation happened.

It appeared then, that the iron itself, by having been once employed to precipitate a solution of silver, was rendered incapable of any further action on any solution of silver. And it is to be observed, that this alteration was produced without the least diminution of its metallic splendour, or change of colour. The alteration, however, was only superficial, as may be supposed; for, by scraping off its altered coat, it was again rendered capable of acting on a solution of silver. Mr. Keir calls iron thus affected *altered iron*; and iron which is clean, and has not been altered, *fresh iron*.

## EXPERIMENT III.

To a phlogisticated solution of silver, in which a piece of bright altered iron lay, without action, a piece of fresh iron was added, which was instantly enveloped with a mass of precipitated silver, and acted on as usual; but what is very remarkable, in about a quarter of a minute or less the altered iron suddenly was covered with another coat of precipitated silver, and was now acted on by the acid solution like the fresh piece. In a little time the silver precipitate was re-dissolved, as usual, and the two pieces of iron were reduced to an altered state. When a fresh piece of iron was then held in the liquor, so as not to touch the two pieces of altered iron, they were nevertheless soon acted upon by the

acid

acid solution, and suddenly covered with silver precipitate as before; and these phenomena may be repeated with the same solution of silver, till the superfluous acid of the solution becomes saturated by the iron, and then the re-dissolution of the precipitated silver must cease.

#### EXPERIMENT IV.

Some dephlogisticated nitrous acid was poured on a piece of altered iron, without any action ensuing, although this acid readily acted on fresh iron; and when to the dephlogisticated nitrous acid, with a piece of altered iron lying immersed in it, a piece of fresh iron was added, this immediately began to dissolve, and soon afterwards the altered iron was acted on also by the acid.

#### EXPERIMENT V.

Upon a piece of altered iron a solution of copper in nitrous acid was poured; but the copper was not precipitated by the iron; neither did this iron precipitate copper from a solution of blue vitriol.

#### EXPERIMENT VI.

Altered iron was acted on by a dilute phlogisticated nitrous acid; but not by a red concentrated acid, which is known to be highly phlogisticated.

#### EXPERIMENT VII.

Some pieces of clean fresh iron wire were put into a concentrated and red fuming nitrous acid. No apparent action ensued; but the iron was found to be altered, in the same manner as it is by a solution of silver, i. e. it was rendered incapable of being attacked either by a phlogisticated solution of silver, or by dephlogisticated nitrous acid.

#### EXPERIMENT VIII.

Iron was also altered by being immersed some little time in a saturated solution of silver, which did not shew any visible action on it.

The alteration thus produced on the iron is very superficial. The least rubbing exposes some of the fresh iron beneath the surface, and thus subjects it to the action of the acid.

It is therefore with difficulty that these pieces of altered iron can be dried, without losing their peculiar property. For this reason Mr. Keir generally transferred them out of the solution of silver, or concentrated nitrous acid, into any other liquor, the effects of which he wanted to examine. Or they may be transferred first into a glass of water, and thence into the liquor to be examined. But it is to be observed, that if they are allowed to remain long in the water, they lose their peculiar property or alteration. They may be preserved in their altered state, by being kept in spirit of sal ammoniac.

#### EXPERIMENT IX.

To a saturated solution of copper in nitrous acid (which was capable of being readily precipitated by fresh iron) some saturated solution of silver was added. From this mixture, a piece of fresh iron neither precipitated silver nor copper; nor did the addition of some dephlogisticated nitrous acid effect this precipitation.

#### EXPERIMENT



**EXPERIMENT X.** A solution of copper, formed by precipitating silver from nitrous acid, by means of copper, was very reluctantly and slowly precipitated by a piece of fresh iron; and the iron thus acted on by the acid was changed to an ochre.

**EXPERIMENT XI.** A saturated solution of silver having been partly precipitated by copper, acquired the property of acting upon fresh iron, and of being thereby precipitated.

**EXPERIMENT XII.** Fresh iron immersed some time in solutions of nitre of lead, or of nitre of mercury in water, did not occasion any precipitation of the dissolved metals; but acquired an altered quality. These metals taken in this respect resemble silver.

**EXPERIMENT XIII.** It is well known that a solution of martial vitriol, added to a solution of gold in aqua regis, precipitates the gold in its metallic state. Mr. Keir remarks, he does not recollect that the precipitation of a solution of silver, by the same martial vitriol, has been observed. However, upon pouring a solution of martial vitriol into a solution of silver, in the nitrous acid, a precipitate will be thrown down, which acquires in a few minutes more and more of a metallic appearance, and is indeed perfect silver. When the two solutions are pretty well concentrated, a bright argentine film swims on the surface of the mixture, or silvers the sides of the glass in which the experiment is made. When a phlogisticated solution of silver is used, the mixture is blackened, as happens generally to a solution of martial vitriol, when a phlogisticated nitrous acid is added to it.

**EXPERIMENT XIV.** Equal parts of water were added to a mixture of phlogisticated solution of silver, and a solution of martial vitriol, in which all the silver had been precipitated, and the dilute mixture was digested with heat; by which means most of the precipitated silver was re-dissolved. Bergman has observed a similar re-dissolution of gold, precipitated by martial vitriol, upon boiling the mixture; but he attributes the re-dissolution to the concentration of the aqua regis by the evaporation. As this explanation did not accord with Mr. Keir's notions, he diluted the mixture with water, and found that the same re-dissolution occurred both with the solution of silver and with that of gold. But he did not find that the re-dissolution ever took place with either of the metals, unless there had been a superabundant acid in the solutions of gold and silver employed.

**EXPERIMENT XV.** Mercury is also precipitated in its metallic state, from its solution in nitrous acid, by a solution of martial vitriol. When the liquor is poured off from the precipitate, this may be changed into running mercury, by being dried near the fire.

**EXPERIMENT XVI.** Mr. Keir found also, that silver may be precipitated in its metallic state, from its solution in vitriolic acid, by addition of a solution of martial vitriol.

A vitriol

A vitriol of mercury may also be decomposed by a solution of martial vitriol; and the mercurial precipitate, which is a black powder, forms globules, when dried and warmed.

#### EXPERIMENT XVII.

Luna cornea is not decomposed by martial vitriol; consequently there is an operation of a double affinity. Nevertheless, this luna cornea may be decomposed by the elements of martial vitriol, while they are in the act of dissolution; that is, the silver may be precipitated in its metallic state, by digesting luna cornea with a dilute vitriolic acid, to which some pieces of iron are added. And it is to be observed, that the reduction of the silver and precipitation take place while the acid is yet unsaturated. Marine acid and iron applied to luna cornea effect the same reduction of the silver to a metallic state, even when there is more acid than is sufficient for both metals\*.

Sulphur combines readily with silver in the dry way; but may be separated by a stronger heat. The sulphur of liver of sulphur likewise blackens silver, and combines with it, whether the silver be immersed in the liquid solution, or exposed to hepatic air.

Aqua regia acts strongly on silver; but precipitates it in the form of luna cornea as fast as it is dissolved. This effect may be easily understood by considering that the nitrous acid dissolves the silver, and the marine precipitates it.

The neutral salts alone do not alter silver either in the moist or dry way; nitre, in particular, does not deflagrate with this metal.

Most metallic substances precipitate silver in the metallic state from its solution. The assayers make use of copper to separate the silver from the nitrous acid used in the process of parting. The precipitation of silver by mercury is very slow, and produces a peculiar symmetrical arrangement, called the tree of Diana. In this, as in all precipitations, the peculiar form may be affected by a variety of concomitant circumstances; for which reason one process usually succeeds better than another. Lemery directs that an ounce of fine silver be dissolved in a sufficient quantity of very pure and moderately strong nitrous acid; that this solution be mixed in a matras, or bottle, with about twenty ounces of distilled water; and that, after the addition of two ounces of mercury, the whole be suffered to repose. During the space of forty days a kind of tree of silver will be formed on the surface of the mercury, with branches greatly resembling a vegetable substance in its ramifications. The foregoing process is said by Macquer to succeed very well; but the following of Homberg is much shorter:

Make an amalgam, without heat, of four drams of leaf silver with two drams of mercury. Dissolve this amalgam in four ounces, on a sufficient quantity of pure nitrous acid of a moderate strength; dilute this solution in about a pound and a half of distilled water; agitate the mixture, and preserve it for use in a glass bottle with a ground stopper. When this preparation is to be used, the quantity of one ounce is put into a phial, and the size of a pea of amalgam of gold or silver, as soft as butter, is to be added; after which the vessel must be left at rest. Soon afterwards small filaments appear to issue out of the ball of amalgam, which quickly increase, and shoot out branches in the form of shrubs.

In the above experiment of Lemery, the nitrous acid deposits its silver at the

\* Keir ends the account of Mr. Keir's experiments.



same time that it takes up mercury; and, in consequence of the liquor being so much diluted, the process goes on slowly, and the precipitated silver has time to arrange itself according to the law of its crystallization, whether that depend on the polarity of its particles, or on any other property not yet explained. In the method of Homberg, there are two circumstances which appear calculated to forward the process: in the first place, the nitrous acid already contains mercury in solution, which may probably render it more disposed to part with the silver; and, in the next place, the mercury is combined with silver or gold in the form of an amalgam. These may perhaps facilitate the precipitation of the silver, by presenting a base for it to combine with; which may be more perfectly at repose, because less agitable than the fluid mercury in the former experiment. After all, however, though the general theory of the experiment is not difficult, yet it does not seem easy to point out the effectual cause of the differences between the two results.

Silver unites with gold by fusion, and forms a pale alloy, as has been already mentioned in treating of that metal. With platina it forms a hard mixture, rather yellower than silver itself, and of difficult fusion. The two metals do not unite well. Silver melted with one tenth part of crude platina, from which the ferruginous particles had been separated by a strong magnet, could not be rendered clear of scabrous parts, though it was repeatedly fused, poured out, and laminated between rollers. It was then fused, and suffered to cool in the crucible, but with no better success. After it had been formed, by rolling and hammering, into a spoon for blow-pipe experiments, it was exposed to a low red heat, and became rough, and blistered over its whole surface. The quantities were one hundred grains of silver and ten grains of platina. Nitre was added during the fusions.

Silver very readily combines with mercury. A very sensible degree of heat is produced when silver leaf and mercury are kneaded together in the palm of the hand. With lead it forms a soft mass, less sonorous than pure silver. With copper it becomes harder and more sonorous, at the same time that it remains sufficiently ductile: this mixture is used in the British coinage. Fifteen parts of silver, alloyed with one of copper, form the compound called standard silver. The mixture of silver and iron has been little examined. With tin it forms a compound, which, like that of gold with the same metal, has been said to be brittle, however small the proportion; though there is probably as little foundation for the assertion in the one case as in the other. With bismuth, arsenic, zinc, and antimony, it forms brittle compounds. It does not unite with nickel. The compound of silver and wolfram, in the proportion of two of the former to one of the latter, was extended under the hammer during a few strokes; but afterwards split in pieces.

Silver is found either native or mineralized. The native silver is found in Peru and various parts of Europe; sometimes in considerable masses, and often diffused through sand, ochre, or lime-stone. It is seldom pure, but is generally alloyed with copper, and sometimes with gold, iron, or regulus of antimony. The mineralized silver contains sulphur and arsenic, or both, with other admixtures.

Native silver may be purified by pounding or washing, or amalgamation with mercury; and the silver itself is refined by cupellation with lead in the same manner as gold. In the large way, the litharge, or vitrified lead, is blown from the surface of the silver by bellows, instead of soaking into the crucible. Gold may be separated from silver by parting with aqua regia, or treatment with

with sulphur in the dry way, which combines with the silver, and leaves the gold disengaged.

The vitreous silver ore is the richest ore of silver, and contains from seventy to eighty pounds of silver in the hundred weight; the rest being sulphur, with rarely any other metal, except a small portion of iron. It is found either in solid large lumps, or inherent in quartz or spar. Its colour generally resembles that of lead; but grows dark by exposure to the air. It usually possesses a slight degree of malleability, and is sufficiently soft to be cut by a knife.

To analyse this ore in the moist way, it may be boiled in nitrous acid, which acidifies the sulphur, and causes great part to fly off in the form of vitriolic acid air. Common salt, or marine acid, will precipitate the silver in the form of luna cornea, which may be either reduced, or accounted for by deducting one fourth of its weight when washed and dried, which fourth of its weight is marine acid.

In the dry way, it may be reduced by exposing it to a heat not sufficient to melt it. In this way the sulphur is dissipated, and the silver remains usually in a fibrous form. Small portions may be conveniently decomposed in this manner by the blow-pipe upon charcoal.

The red silver ore is a heavy shining substance, either transparent or opaque; sometimes gray or blackish, but always reddish when powdered: it usually contains more than half, and sometimes three-fourths of its weight of silver, the rest being arsenic and sulphur.

In the moist way this ore is analysed by reducing it to fine powder, and boiling it with diluted nitrous acid. The residue, which contains the sulphur and the arsenic, must be edulcorated with water; and the arsenic may be dissolved by boiling in a sufficient quantity of aqua regia. If the sulphur should retain any luna cornea, it may be separated by keeping it for some days in a closed vessel, with its own weight of diluted caustic volatile alkali. The clear nitrous solution being mixed with the water used in the edulcoration, affords a precipitate of luna cornea by the addition of sea salt, which may either be reduced, or accounted for in the same manner as in the assay of the vitreous silver ore.

Silver united with sulphur, arsenic, and copper, is generally called the white ore of silver. One hundred grains of this being reduced to a powder, and gently boiled for an hour in more than twelve times its weight of diluted nitrous acid, the copper and silver are dissolved, and a white residuum remains. The silver is precipitated in the metallic form by the immersion of a clean plate of copper; and the copper being afterwards precipitated by the addition of volatile alkali, may be accounted for by allowing 194 grains of the precipitate to 100 of the copper, and deducting the loss sustained by the plate of copper which was immersed in the solution. The white residuum may be deprived of its arsenic and iron by boiling in marine acid. The arsenic may be precipitated by the addition of water; and afterwards the iron, if any, by Prussian alkali. The undissolved sulphur may be treated with volatile alkali, to try whether it contains either copper or luna cornea.

The other ores of silver, of which there is considerable variety, may be analysed by varying the processes according to the supposed or known general contents of the ore \*.

\* For which consult Bergman's Treatise on the Art of Assaying in the Humid Way, inserted in the second volume of the English translation of his Opuscula, or Essays.



Sulphureous and arsenical silver ores may be assayed by roasting, and subsequent fusion with a greater or less quantity of flux. In the fusion, the silver is obtained alloyed with lead, copper, or iron, which may be separated by cupellation with lead, and the silver left pure. The fineness of silver is denoted by the assayers by mentioning the number of pennyweights and grains of pure silver contained in the ounce. So that if an ounce of silver be found to lose half a pennyweight by cupellation, it is said to be eleven pennyweights twelve grains fine; if it lose a whole pennyweight, it is said to be eleven pennyweights fine, &c. Silver is likewise tried by the touch, in the same manner as gold. For this purpose the assayers are provided with a set of needles, or small bars; the first of which contains  $\frac{1}{10}$  part of its weight of copper, and the rest silver; the second contains  $\frac{2}{10}$  parts of copper; the third  $\frac{3}{10}$  parts; and so on to the last, which contains  $\frac{9}{10}$  parts of copper to one of silver. By the resemblance of colour on the touchstone, an estimate may be made of the fineness of the silver to something nearer than the 30th part of the whole, which is a considerable acquisition in the examination of small articles, such as rings, trinkets and the like. It is true indeed that the use of the touch supposes the precious metal to be alloyed with copper only, which may not be the case; and consequently the assayer is liable to be deceived in this respect; but he may in this case have recourse to aqua fortis, on the blow-pipe, in the same manner as directed in the article gold.

In the large works, where silver is extracted, the processes are grounded on the properties already described. Native silver is triturated with mercury; after which the amalgam is washed, to separate the earthy particles; and the quicksilver separated, partly by pressure in leathern bags, and partly by distillation in iron retorts.

Rich sulphureous ores are roasted, and fused with lead, to refine the silver by cupellation. The poorer ores, which contain copper, are fused with pyrites, which affords a mass consisting of copper, sulphur, and silver. Lead is then added, and the mass treated in the way of eliquation. The lead flows out, carrying the silver with it; and lastly, these two metals are separated by the test, on which the lead is converted into litharge, and the silver remains pure.

The uses of silver are well known: it is chiefly applied to the forming of various utensils for domestic use, and as the medium of exchange in money. Its disposition to assume a black colour by tarnishing, and its softness, appear to be the chief objection to its use in the construction of graduated instruments for astronomical and other purposes, in which a good white metal would be a desirable acquisition.

**SILVERING.** There are various methods of giving a covering of silver or silvery aspect to the surfaces of bodies. The application of silver leaf is made in the same way as that of gold, for which see GILDING. Copper may be silvered over by rubbing it with the following powder: Two drams of tartar, the same quantity of common salt, and half a dram of alum, are mixed with fifteen or twenty grains of silver precipitated from nitrous acid by copper. The surface of the copper becomes white when rubbed with this powder, which may afterwards be brushed off and polished with leather. The saddlers and harness makers cover their wares with tin for ordinary uses, but a cheap silvering is used for this purpose as follows: Half an ounce of silver that has been precipitated from aqua fortis by the addition of copper, common salt and sal ammoniac, of each two ounces, and one dram of corrosive sublimate, are triturated together, and made into a paste with water; with this, copper utensils of every kind, that

have been previously boiled with tartar and alum, are rubbed, after which they are made red hot, and then polished. The intention of this process appears to be little more than to apply the silver in a state of minute division to the clean surface of the copper, and afterwards to fix it there by fusion; and accordingly this silvering may be effected by using the argentine precipitate here mentioned, with borax or mercury, and causing it to adhere by fusion. The dial plates of clocks, the scales of barometers, and other similar articles are silvered by rubbing upon them a mixture of luna cornea, sea-salt, and tartar, and afterwards carefully washing off the saline matter with water. In this operation, the silver is precipitated from the marine acid, which unites with part of the coppery surface. It is not durable, but may be improved by heating the article, and repeating the operation till the covering seems sufficiently thick. The silvering of pins is effected by boiling them with tin filings and tartar. The explanation of this effect is difficult. It should seem as if the order of the affinities was changed by the increase of temperature; so that the tin may be taken up at a lower temperature by the acid, and give place to the brass at a greater heat. But see **TINNING**.

In the silvering of looking-glasses, like the preceding operation, no silver is used. A leaf of tin foil, which must be thicker the larger its dimensions, is evenly spread upon a smooth stone table furnished with a rim. Upon this mercury is poured in a small quantity at first, and softly brushed about till the whole surface of the tin appears bright by amalgamation. At this period, the mercury has corroded the upper surface only of the tin; but if the operation were to rest here, its texture would soon be entirely destroyed by a total combination. The workman then pours a considerable quantity of mercury upon the table. A sheet or piece of paper with a neat cut edge is then applied over one of the rims of the table, and upon it the plate of glass intended to be silvered. The plate is then slid on ward, and comes in contact with the mercurial surface, so as not only to prevent the interposition of bubbles of air, which would ensue from a perpendicular application, but likewise in a great measure to drive the dust and other impurities before it. As soon as the whole surface of the glass is thus applied to the mercury, the paper is withdrawn, and weights placed on the glass, so as to bring it into close contact with the amalgamated tin foil. The superfluous mercury is then decanted off, and the glass suffered to remain undisturbed for a day or more. During this time, the mercury applied between the surface of the glass and the tin, becomes gradually absorbed by the latter, and forms a hard amalgam, which is not easily injured or removed, and is further defended by the frame into which looking-glasses are usually set.

The convex surfaces of glass mirrors are silvered in the same manner, but instead of a flat table, a mould of plaster of Paris is made use of. Hollow mirrors or globes are silvered by an amalgam consisting of one part by weight of bismuth, half a part of lead, the same quantity of pure tin, and two parts mercury. The imperfect metals are to be first fused together, and the mercury then added when the mixture is almost cold. A very gentle heat is sufficient to fuse this amalgam. In this state it is poured into a clean glass globe intended to be silvered, by means of a paper funnel which reaches to the bottom. At a certain temperature, it will stick to the glass, which by a proper motion may thus be silvered completely, and the superfluous amalgam poured out. The appearance of these toys is varied by using glass of different colours, such as yellow, blue or green.

**SINOPE** is a dark red jasper or flint, which strikes fire with steel, and affords



in the dry way 10 per cent. of iron, and melts into a black slag. Rimm. Hist. Ferri, § 189. If tried with the Prussian alkali, it would probably shew eighteen or twenty parts of iron, as this always separates nearly double the quantity of iron that can be extracted in the dry way.

**SINTER.** See STALACTITES.

**SLATE.** This name is given to argillaceous opake stones, which possess the well known property of breaking or splitting into plates or laminae. The sixth, seventh, and eighth species of Kirwan's argillaceous gems comprehend the slates or shists.

Of the roof slate, or shistus tegularis, he reckons four varieties, none of which has been hitherto analysed, except the blueish-purple slate, chiefly used in London, which he examined, and to which, as to a standard, he refers the other sorts.

**VARIETY I.** Clay intimately mixed with 1.77 of its weight of siliceous earth, 0.3 of its weight of magnesia, 0.15 of calcareous earth, both slightly aerated, and nearly 0.54 of its weight of iron, besides a slight admixture of mineral oil. This forms blueish-purple slate. It does not strike fire with steel, and may be lightly scraped with the nail: it is very brittle, and of a lamellar texture: its specific gravity is 2.876: when in pieces of  $\frac{1}{4}$  of an inch thick, or less, it gives a clear sound if struck: its grain is moderately fine: it is never transparent: it slightly effervesces with acids when reduced to powder, otherwise not: when heated red, it loses something more than 2 per cent. of its weight, slightly detonates with nitre, and then assumes a brownish red colour, but calcination does not render it magnetic: in a stronger heat it is fusible without addition, and forms a black scoria: it is difficultly dissolved by mineral alkali in the dry way, more easily by borax, though with little effervescence, and also by microcosmic salt with some effervescence. Mr. Gerhard remarks, that it melts with equal ease in chalk or clay vessels.

Colourless acid of nitre, after standing on it two months in cold, assumes a green colour.

Kirwan found 100 grains of it to contain about 46 of siliceous earth, 26 of argill, 8 of magnesia, 4 of calcareous earth, and 14 of iron. Part of the iron seems to be in a phlogisticated state, from its union with the oil, and part in a dephlogisticated state, or that of a red calx. This is united to the argillaceous part and siliceous, and is very difficultly separated.

**VARIETY II.** Pale, slightly purple, or blueish shistus. This stone is harder than the foregoing, its laminae thicker, and its texture coarser: it seems to contain a larger proportion of the siliceous, and a smaller of the martial ingredient.

**VARIETY III.** Blue shistus. The proportion of the earthy ingredients being the same as in the first variety, that of the martial ingredients seems to be smaller.

Other stones are also used for covering houses in various countries, but they are easily distinguished; as their laminae are much thicker, their surface more uneven, and their texture coarser. They chiefly belong to the class of sand stones, or to the calcareous genus.

**VARIETY IV.** Dark blue slate, shistus scriptorius. It effervesces more briskly with acids, and seems to contain more magnesia, and less iron, than the first variety: its specific gravity is 2.701.

The pyritaceous species consists of earth mixed with a variable proportion of pyrites, with a little magnesia and calcareous earth.

Its colour is gray, brown, blue, or black: it is more or less decomposable by exposure.

exposure to the air, according to the quantity of the pyritous ingredient and the state of the iron in the pyrites: if the iron be in a semi-phlogisticated state, it is easily decomposed; but if the calx of iron be already much dephlogisticated, it will be decomposed but slowly, if at all. Aluminous shistus is of this species.

The bituminous shistus is intimately mixed with a notable proportion of mineral oil or bitumen.

It is generally black, of a lamellar texture, of different degrees of hardness, but never gives fire with steel: it emits a strong smell when heated, and sometimes without heat; and does not shew white when scraped.

To these may be added, 1. The argillaceous shistus or flag-stone. It consists of clay mixed with from three to four tenths of its weight of silice, and a little of the yellow or red calx of iron. It is of a grey, yellowish, or reddish white colour; does not give fire with steel, nor effervesce with acids: its specific gravity is from 2.6 to 2.78: it is in some places used for covering of houses, but mostly for flooring; it is sometimes compact, and sometimes sandy, and then its specific gravity is smaller.

2. The argillaceous grit, free-stone, or sand stone. This may be cut easily in all directions: its texture is more or less porous, equable, and rough to the touch: it exhales an earthy smell when fresh broken and breathed upon: it does not give fire with steel, nor effervesce with acids. That from Hollington, near Uttoxeter, is of a whitish or yellowish gray, and its specific gravity 2.288. That from Knipersly, in Staffordshire, is of a blueish gray, and so fusible as to be used for a fire-stone: its specific gravity is 2.568.

SMALT. See ZAFFRE.

SMARAGDUS. See PRECIOUS STONES, No. VII.

SMECTIS. See STEATITES.

SMELL, PRINCIPLE OF. Substances dissolved or suspended in the atmosphere are found to act with peculiar energy on the organs of smell. Such permanently elastic fluids as are destructive of animal life, as for example, alkaline air emitted from the concrete alkali commonly called smelling salts, vitriolic acid air formed when sulphur is burning, nitrous air from aqua fortis, and the like, produce effects to which scarcely any individual is a stranger. Every chemical operation is attended with the extrication of more or less volatile matter. Even the metals and glass affect the organ of smell, probably by some evolution; and the smells emitted by organized substances in every stage of their existence, are among the most remarkable of their secondary properties.

The principle of smell in plants appears to be of an exceedingly subtile nature. It seems in general to reside in the essential oil, and composes an extremely small part of the weight of vegetables, as may be inferred from the loss of fragrance sustained by essential oils, with little or no loss of their weight. This however does not necessarily suppose that the whole principle of smell has flown off; because it may with equal probability be supposed to have entered into combination with some of the other principles of the substance which afforded it. Distillation with spirit of wine is used to extract the fragrant principle from plants. A considerable proportion of this matter may be obtained by distillation with water, in which it comes over probably diffused with a small proportion of essential oil. It has been supposed to consist of an elastic fluid of a peculiar nature.

SMELTING OF ORES. The separation of metallic substances from their ores in the large way by heat, is called smelting. For the processes, See ORES.

SNOW.



**SNOW OF ANTIMONY.** This name has been given to the white calx obtained by sublimation from regulus of antimony.

**SOAP** is a saline compound, formed from fat or inflammable bodies, which not being soluble in water by themselves, compose, by the assistance of salts, a homogeneous mass soluble in water. These substances are slippery to the touch, soluble in water and spirit of wine, and commonly lather and froth with these fluids, upon being agitated with them; they also render several other substances miscible with water. They are discriminated from each other, not only by the various salts, but likewise by the different sorts of fat substances employed in their preparation. Similar combinations also are found ready formed in nature, though these are less in use, and require to be adapted by art to the different purposes to which they may be applied.

Different vegetables very evidently exhibit by nature a saponaceous quality in their composition, of which soap wort, the soap-berry tree (*Sapindus saponaria*), and the common night-shade, may be adduced as instances. Now since the period that we have been convinced of the presence of alkaline salts in vegetables, nothing is easier than to conceive the origin of a mixture of this kind. In proportion therefore as this salt and the oily parts exceed the rest in quantity, and the force of the alkali is not weakened at the same time by the presence of a mineral acid, such vegetable will be more or less of a saponaceous nature. Sometimes also, though more rarely, a saponaceous compound is met with in vegetables which consist of oleaginous particles and an acid. For this reason it is necessary in every case, previous to attempting to ascertain the composition of one of these compounds, to see of what kind it is. With this view, the watery extract of the saponaceous plant needs only to be mixed with a solution of fixed alkaline salt, and notice taken whether any precipitation or separation of the constituent parts ensues or not. If in this operation the mixture is not observed to become turbid, but that an acid on being added to it produces this effect, it may reasonably be inferred, that this saponaceous compound has an alkaline salt for its basis. But if upon the addition of an acid to such extract no alteration ensues, and it is, on the contrary, rendered turbid by an alkali, it may be concluded that the composition is saponaceous with an acid basis.

A perfect soap cannot be produced by art with acids. From the commixture of fluid acids and oily substances, no other than greasy, saponaceous masses are produced, which, though they are miscible with water, cannot be brought into a solid and concrete state, and at the same time preserve their saponaceous qualities.

The alkaline salts, on the contrary, are intermediate substances, by which all oleaginous or other inflammable bodies may be brought into a perfectly saponaceous state. But in order to promote the combination proposed, they must necessarily be deprived of fixed air, by boiling with quick-lime.

With the fixed alkaline salts, the mineral as well as vegetable alkali, tallow-soaps are prepared in the following manner: One part of either of these alkaline salts, and about two parts of quick-lime, or as much as is requisite to render them perfectly caustic, are to be mixed together, and made into a strong ley, with the necessary quantity of water. This ley is then made to boil with three parts of tallow or fat over a gentle fire, and kept continually stirring, till the mixture becomes thick, and ceases to adhere to the hand, when a little is taken out of it for a sample. Towards the end, a proportional quantity of common salt is added, by which the soap acquires a greater degree of hardness.

This

This effect has been accounted for on various suppositions. It has been said, that the quantity of water present is diminished by the abstraction of as much as the salt requires for its solution; a circumstance probably of little consequence. Again, the soap is rendered less soluble in the water by this addition; and therefore more readily separates. But the most important effect seems to be, that the marine acid of the salt attracts the vegetable alkali of the soap, and gives its own mineral alkali in return, which is known to afford a much harder soap. The weight of the soap here acquired is commonly, as Wiegleb says, double that of the tallow employed in making it. In the same manner a wax soap may be prepared either of yellow or white wax, which is about three times the weight of the wax, is very hard and firm, and has an agreeable smell of almonds. The Gravenhorsts in Brunswick likewise prepare a soap of cocoa butter for medical uses. Sperma cæti also may be made into soap with a caustic ley.

Macquer gives us the following process for oil soap: One part of quicklime and two parts of good Spanish soda are boiled together during a short time, with twelve times as much water, in an iron cauldron. This lixivium is to be filtered, and evaporated by heat, till a phial which is capable of containing an ounce of water shall contain an ounce and three gros of this concentrated lixivium. One part of this lixivium is to be mixed with two parts of oil of olives, or of sweet almonds, in a glass or stone-ware vessel. The mixture is to be stirred from time to time with an iron spatula, or with a pestle, and it soon becomes thick and white. The combination is gradually completed, and in seven or eight days a very white and firm soap is obtained.

For the coarser sorts of soap cheaper oils are employed, such as oil of nuts, linseed, hemp, fish, &c. Either of these kinds of soap, to be good, must not feel greasy or unctuous in water, nor exhibit any vestige of fat upon the water. It ought farther to dissolve easily in water, and lather well, as likewise be easily soluble in spirit of wine. It must not become moist in the air, nor throw out a saline efflorescence on its external surface. When a solution of soap in spirit of wine is poured into river or spring water, a precipitation ensues, and a great part of the precipitate is no longer soluble in water. All soaps are decomposed again by acids, and the fat matter separated from them. The alteration however, which the fat and oils undergo on this occasion, is very remarkable. They are now soluble in spirit of wine, whereas before the case was quite otherwise; the cause of which depends on the action of the matter of fire upon these bodies; and indeed the naked fire manifestly exerts the same effect upon them in such cases, in which it converts them into empyreumatic oils. In the southern countries, mineral alkali, but in the northern countries the common vegetable alkali, is more commonly employed in the manufacture of soap. With mere lime-water a saponaceous greasy mixture only, but no solid soap, can be obtained. Besides the above-mentioned fat substances, a resinous soap may also be made from the coarser kinds of resin with caustic ley. The compound resulting from this union partakes at the same time of the properties of oil and of alkali; but these properties are modified and tempered by each other, according to the general rule of combinations. Alkali formed into soap has not nearly the same acrimony as when it is pure; it is even deprived of almost all its causticity, and its other saline alkaline properties are almost entirely abolished. The same oil contained in soap is less combustible than when pure, from its union with the alkali, which is an unflammable body. It is miscible, or even soluble in water to a certain degree, by means of the alkali. Soap is entirely soluble.



luble in spirit of wine, and still better in *aqua vitæ* sharpened by a little alkaline salt, according to an observation of Mr. Geoffroy.

When oil unites with alkali in the formation of soap, it is little altered in the connexion of its principles; for it may be separated from the alkali by decomposing soap with any acid, and may be obtained nearly in its original state. By the accurate investigation that Mr. Geoffroy has made of soap, by decomposing it thus by means of an acid, he found that two ounces of this compound consist of one ounce three gros and one scruple of oil, one gros and a scruple of marine alkali deprived of all moisture, or twice the quantity of this salt containing the water of its crystallization; and lastly, two gros and four grains of water. This latter quantity of water is nevertheless variable, according to the condition of the soap; for it may be much more or much less dry.

Concerning the decomposition of soap by means of acids we must observe, first, that all acids, even the weakest vegetable acids, may occasion this decomposition, because every one of them has a greater affinity than oil with fixed alkali. Secondly, these acids, even when united with any basis, excepting a fixed alkali, or the inflammable principle, are capable of occasioning the same decomposition; whence all ammoniacal salts, all salts with basis of earth, and all those with metallic bases, are capable of decomposing soap, in the same manner as disengaged acids are; with this difference, that the oil separated from the fixed alkali, by the acid of these salts, may unite more or less intimately with the substance which was the basis of the neutral salt employed for the decomposition.

Soap may also be decomposed by distillation; as Lemery has shewn. When first exposed to fire, it yields a phlegm called by him a spirit; which nevertheless is neither acid nor alkaline, but some water which enters into the composition of soap. It becomes more and more coloured and empyreumatic as the fire is increased, which shews that it contains the most subtle part of the oil. It even seems, as Macquer remarks, to raise along with it by help of the oil, and action of the fire, a small part of the alkali of the soap; for, as the same chemist observes, it occasions a precipitate in a solution of corrosive sublimate. But the modern discovery of the composition of volatile alkali leads us to infer, that the phlogisticated air of part of the mucilage of the oil formed this salt, by uniting with the inflammable air in the heat of destructive distillation. See **ALKALI VOLATILE**. After this phlegm, the oil rises altered, precisely as if it had been distilled from quick-lime, that is, empyreumatic, soluble in spirit of wine, at first sufficiently subtle, and afterwards thicker. An alkaline residuous coal remains in the retort, consisting chiefly of the mineral alkali contained in the soap, and which may be disengaged from the coal by calcination in an open fire, and obtained in its pure state.

As all oils contain an acid more or less combined, which may also be more or less disengaged by the oil becoming rancid, by the action of heat, or by combination with other bodies, probably a portion of the alkali of the soap is saturated with the acid of the oil, especially after the distillation of the soap. But this matter has not been so well examined, that we can affirm any thing concerning it.

Alkaline soaps are very useful in many arts and trades, and also in chemistry and medicine. Their principal utility consists in a deterfve quality that they receive from their alkali, which, although it is in some measure saturated with oil, is yet capable of acting upon oily matters, and of rendering them saponaceous

ceous and miscible with water. Hence soap is very useful to cleanse any substances from all fat matters with which they happen to be soiled. Soap is therefore daily used for the washing and whitening of linen; for the cleansing of woollen cloths from oil, and for whitening silk, and freeing it from the resinous varnish with which it is naturally covered. Pure alkaline lixiviums being capable of dissolving oils more effectually than soap, might be employed for the same purposes; but when this activity is not mitigated by oil, as it is in soap, they are capable of altering, and even of destroying entirely by their causticity most substances, especially animal matters, as silk, wool, and others: whereas soap cleanses from oil almost as effectually as pure alkali, without danger of altering or destroying; which renders it very useful.

Volatile or essential oils are not united to alkaline salts but with great difficulty. Hence, according to Wiegleb, Starkey's soap is the only soap of this kind known. This soap is prepared by pouring four parts of oil of turpentine upon one of pulverized highly caustic fixed alkali in an alembic, digesting them together for some time in a gentle heat, and lastly, distilling the oil over the helm, and pouring it back again several times, till at length the salt will take up no more of it, and has acquired a saponaceous nature. With empyreumatic oils, a combination of this kind has not as yet succeeded; the formation of a soap of camphire however succeeded perfectly well.

Shorter methods have been sought after for the preparation of Starkey's soap, by several chemists; and amongst these is the illustrious Stahl; who, considering water as part of the combination of every soap, and even that it is a medium by which the salt and oil are united together, directs, that after having mixed oil of turpentine with very hot alkali, and having shook them together, this mixture should be exposed in a moist place, that all the portion of alkali which does not unite with the oil may deliquate, and be separated from the part of the mixture that is combined; that this alkali should then be dried, and new oil poured upon it, as at first; and lastly, that this method should be continued till the whole be reduced into soap; and thus the operation will, as he affirms, be greatly shortened. Nevertheless, later chemists, not satisfied with this method of Stahl, have endeavoured to simplify still more this operation. Mr. Rouelle the younger has published, in the *Journal de Medecine*, that he has discovered a more expeditious method than all those hitherto known for the preparation of this soap. Mr. Baumé has also published in the *Gazette de Medecine* a method of making it in a few hours. It consists in triturating, during a long time, alkaline salt upon a porphyry, and in adding to this salt, during the trituration, oil of turpentine. According to this able chemist, the thick resinous part only of this oil can truly combine with fixed alkali: and this combination is effected only while the more volatile and attenuated part of the oil is dissipated. For which reason, according to him, a very great quantity of oil of turpentine is requisite for the formation of Starkey's soap, which quantity of oil is indeterminate, as, the more volatile and ethereal it is, the more of it is required; and also the trituration upon the porphyry, by promoting the evaporation of the subtle part of the oil, accelerates considerably the operation of Starkey's soap.

Another artist says, in the *Gazette de Medecine*, that the operation may be much abridged, by adding to the new mixture a certain quantity of this soap ready made; which corresponds with Baumé's opinion. Lastly, Baumé has found, that the addition of a little turpentine, or of ordinary soap, considerably



rably abridges the operation; and this also confirms his opinion, which seems to be very probable. Macquer has made several judicious observations on this compound.

He thinks this preparation seems to be uncertain, and ill chosen. For, besides that the true soap of Starkey, that is, the intimate combination of ethereal oil of turpentine with fixed alkali, according to the usual idea of it, is a thing probably impossible; it may be affirmed that the saponaceous compounds obtained by any method of mixing oil of turpentine with fixed alkali do not long remain in the same state, and by time necessarily undergo perpetual alterations.

To be fully convinced of this truth, we may compare together not only these soaps made by different processes, but also the same soap, a longer or shorter time after it has been made, and we shall find considerable differences in their colour, smell, and consistence. We shall find that those deliquate, and are partly resolved into liquor by the air, that have been made with a too ethereal oil, which is incapable of saturating well the fixed alkali; that others acquire by time a pitchy, yellowish, semi-transparent and resinous appearance, which contain too large a quantity of thick residuum of oil of turpentine. Those soaps which seem to be the best made, which contain a proper quantity of oil of turpentine, which are neither too ethereal nor too thick, preserve longer their white colour and the consistence of true soap: but they nevertheless participate more or less of the faults we have mentioned. Lastly, all these soaps are liable to contain a considerable quantity of a sort of neutral salt, formed by the acid of the oil of turpentine united with a part of the alkali of the soap. This salt crystallizes upon the surface, and even within the soap, which in time becomes quite penetrated and stuck all over with a saline efflorescence. These bad qualities and alterations of Starkey's soap cannot be avoided by any method, as they depend on the nature of essential oils, which we cannot change. These soaps are known to contain a volatile and superficially combined acid, which unfolds itself more and more, or which is engaged more intimately with a portion of oil, to which it gives a thicker consistence. We are no less certain that the most ethereal part of essential oils, or their spiritus rector, is so volatile, that however attentive we may be to preserve it, it will gradually dissipate in time. In a word, we know from experience, that all essential oils are drying, and are much more spontaneously alterable than any others; and that these spontaneous alterations cannot be prevented by the imperfect combination which they are capable of forming with an alkali. On the contrary, this alkali, by absorbing their acid, and by facilitating the dissipation of their ethereal part, with which the alkali is not capable of forming a true union, can only hasten the alterations to which the oil is naturally disposed.

From all this he concludes that Starkey's soap is a difficult, uncertain, variable preparation, which is continually changing its nature, and consequently its medicinal virtues. This latter inconvenience, although it were the only one, would be sufficient to make us reject this preparation. And therefore, as is probable, a saponaceous substance, partaking of the properties of fixed alkali and of an essential oil, would be useful in medicine; ordinary soap, incorporated extemporaneously with any quantity of essential oil which shall be judged proper, might be substituted instead of Starkey's soap.

Volatile alkali is in its nature but ill adapted for remaining fixed in bodies, till a perfect combination can take place with various kinds of fat; though in its caustic state, by bare mixture alone, it imparts a saponaceous quality to lard, butter,

butter, and fat oils, inasmuch that they become soluble in spirit of wine. Consequently it is only capable of uniting with volatile ethereal oils, from which concrete and fluid volatile oily salts are compounded. Of the former kind are the smelling salts, or mild volatile alkali sublimated with the addition of a fragrant or essential oil. Otherwise it may be expeditiously made, indeed extempore, by a mixture of three parts of purified alkali, one part of pure sal ammoniac, and an addition of one or more parts of scented ethereal oils ad libitum, and kept in a phial well stopped. In the main too the salt of hartshorn above described resembles this. Of liquid volatile oily salts, the empyreumatic urinous spirits, Sylvius's volatile spirit (sal volatile oleosum Sylvii), likewise what is called Eau de luce, may be considered as instances. For the latter, Wieglieb directs that in two drams of the strongest alcohol be dissolved from six to ten drops of rectified oil of amber, and afterwards one scruple of white soap; to this mixture is then to be poured an ounce of the caustic volatile alkali, and the whole well shaken together. See EAU DE LUCE.

Metallic soaps, or combinations of the metallic calces with oils, are most expeditiously prepared by adding a solution of soap to a solution of the metal in an acid. The acid and the alkali unite, and the metallic calx forms in general an insoluble combination with the oil, which therefore falls down. Fourcroy thinks that some of these might be useful as pigments.

Various other saponaceous bodies may be mentioned, which exhibit effects similar to that of soaps upon substances and other bodies insoluble in water, and make them at least miscible with it. This property sugar exhibits with respect to ethereal oils, almonds in substance, the yolk of eggs, thick mucilage of gum arabic, gum tragacanth, the kernels of quinces, and mallow root, upon camphire, turpentine, wax, and different resins; to effect which purpose, soap itself may be used with advantage.

SOAP-STONE. See LAPIS OLLARIS.

SOAP-WORT. See SAPONARIA.

SODA. See ALKALINE MINERAL.

SOIL. See ARABLE LANDS.

SOLDERS and SOLDERING. Solders consist merely of simple or mixed metals, by which alone metallic bodies can be firmly united with each other. In this respect it is a general rule, that the solder should always be easier of fusion than the metal intended to be soldered by it: next to this, care must also be taken that the solder be as far as is possible of the same colour with the metal that is to be soldered.

For the simple solders, all the simple metals may be used according to the nature of the metal that is to be soldered. For fine steel, copper, and brass work, gold and silver may be employed. In the large way, however, iron is soldered with copper, and copper and brass with tin. The most usual solders are the compound, which are distinguished into two principal classes, viz. hard and soft solders. The hard solders are ductile, will bear hammering, and are commonly prepared of the same metal with that which is to be soldered, with the addition of some other; by which a greater degree of fusibility is obtained, but which is not always required to be easier of fusion. Under this head comes the hard solder for gold, which is prepared from gold and silver, or gold and copper, or gold, silver, and copper. The hard solder for silver is prepared from equal parts of silver and brass, but made easier of fusion by the admixture of a sixteenth part of zinc. The hard solder for brass is obtained from brass mixed with a sixth, or an eighth,



or even one half of zinc, which may also be used for the hard folder or copper. It is sold in the shops in a granulated form, under the name of Spelter Solder. The soft folders melt easily, but are partly brittle, and therefore cannot be hammered. Of this kind are the following mixtures: tin and lead in equal parts; of still easier fusion is that consisting of bismuth, tin, and lead, equal parts; or of two parts of bismuth, of tin and lead each one part.

In the operation of soldering, the surfaces of the metal intended to be joined must be made very clean, and applied to each other. It is usual to secure them by a ligature of iron wire, or other similar contrivance. The folder is laid upon the joint, together with sal ammoniac or borax, or common glass, according to the degree of heat intended. These additions defend the metal from calcination. Glaziers use resin; and pitch is sometimes employed.

Tin foil applied between the joints of fine brass work, first wetted with a strong solution of sal ammoniac, makes an excellent juncture; care being taken to avoid too much heat.

**SOLUTION.** This word is used by chemists to denote the perfect union of a fluid substance with any other body. It is applied without distinction to the act of union, and to the compound resulting from that act. The fluid is called the solvent, but no particular appellation has been given to the bodies dissolved.

Solution is different from mere mechanical suspension. One of its most distinguishing criterions is transparency in the compound. The act of solution being performed at the surfaces of bodies, will be more speedy, the smaller the particles. Hence the advantage of pulverizing previous to solution. See **ATTRACTION**.

**SONOROUSNESS.** Daily experience shews that the sounds emitted by various bodies when struck are very different. On the nature of sound, writers upon the mechanical philosophy may be consulted. The sensation is produced by a tremulous or vibratory motion communicated from the sonorous body to the organ of the ear. The medium of communication seems to admit of no exclusion; but, as far as we yet know, the sound is communicated to greater distances undiminished, the denser and perhaps the more elastic the subject of communication.

Thus Dr. Franklin found that the striking of two stones together under water was audible, with no apparent diminution, at the distance of two miles, by an observer whose head was plunged in the same continued mass of water. And so likewise the scratching of a pin, or the beating of a watch, may be very distinctly heard from one end to the other of a piece of timber of any length, if the ear be applied close to the timber, or if it be pressed between the teeth, even though the ears be closed. The air of the atmosphere is however the common medium of sound. By experiments with stretched strings, bells, and other musical instruments, it is not only found that vibration is the cause of sound, but the actual frequency of those vibrations may be numerically ascertained. Intensity of sound depends on the force of each vibration, and acuteness on their frequency. Hence the sonorous qualities of bodies and other metals must depend in a great measure on their elasticity, and considerably on their figure and density.

**SOOT** is a collection of substances formed by the matter of the flame of inflammable bodies, but which have escaped combustion from not having sufficient contact with the air. This matter, which fixes itself to the internal surface of chimnies, is always of a black colour, more or less brownish. This colour it receives from an oil that is burnt and half reduced to the state of coal.

As all inflammable bodies undergo a total decomposition during their inflammation, all the volatile principles which they contain, and even a part of the fixed

fixed principles, by means of those which are volatile, are raised in vapours, some part of which burns with flame, is totally dissipated in the elastic state, and another part is sublimed, and adheres to the first cold bodies which it meets.

Soot is, as we have now observed, the portion of fuel which is reduced to black smoke, and which has not been inflamed from want of sufficient contact with air. For if the vapours exhaling from an inflammable body strongly heated were so rarefied, that each of their parts should be altogether surrounded by air, they would all burn with flame; and then we should have no smoke or soot, or at least this soot would not be black, and would contain nothing inflammable. For which reason the greater quantity of air is admitted amongst bodies which burn with flame, the less smoke and soot we have; and also, the soot proceeding even from bodies of the same kind must be very different, according to the manner in which they are burnt. See LIGHT. In general, we can say nothing that will be constantly applicable to the nature and principles of soot, as its differences arise not only from the causes above mentioned, but also from the nature of the inflammable substances which produce it. Thus vegetables, from which little or no volatile alkali is obtained, must furnish a soot different from that of animal matters; and the soot of a pure oil must be different from that of a plant containing all its principles. But these differences have not yet been observed, because chemists have not attended to this subject.

We know only that the ordinary soot of chimnies has an acrid, bitter, empyreumatic and disagreeable taste; that water can extract from it a dusky-coloured matter, which shews that it contains saline, oily, saponaceous parts; that it is capable of being again burnt very vividly and with much flame, as when chimnies are set on fire.

If this soot be distilled in a retort, we obtain from it phlegm, volatile alkali, partly concrete and partly liquid, a black empyreumatic oil, and in the retort much coal remains, from which fixed alkali may be extracted by incineration and lixiviation. Some acid also may possibly be obtainable from certain soots; and generally towards the end of the distillation, when the heat is strong, a little sal ammoniac is sublimed.

As every soot, even that which proceeds from vegetable matters, contains a good deal of volatile alkali, Macquer infers that the principles of vegetables suffer by combustion in an open fire, changes similar to those occasioned by putrefaction. Besides, the quantity of fixed coal which remains after the distillation of soot, and which furnishes a fixed alkali, together with much earth, by incineration, shews that a very considerable quantity of the fixed principles of inflammable bodies is carried off, and even raised to a great height, by means of their combustion with flame: but, as we have said, soots are very different; and the matter is but little known, and requires further researches.

**SORREL, SALT OF.** For the purpose of preparing salt of wood-sorrel, *oxalis acetosella* Linn. the wood-sorrel is bruised in a mortar, and the whole of its juice expressed. After it has stood for some time, the grosser earthy particles subside to the bottom, and the liquor becomes limpid and clear, after which it is filtered. The clear juice is then evaporated to less than one half, and set by in a cool place to crystallize. After some time, the remaining liquor is poured off from the crystals, and then evaporated, filtered, and crystallized afresh. This process is continued till the whole of the salt is extracted from the juice. According to Savary's experiments, fifty pounds of fresh wood-sorrel yielded twenty-five pounds of juice, from which were obtained two ounces and a half of pure salt.

This



This salt consists of a peculiar acid, which for this reason is called acid of wood-  
 sorrel, united to vegetable fixed alkali, as Wiegleb proved in an express treatise on  
 the subject. Consequently it is a neutral salt, supersaturated with acid. When  
 it is combined with more alkali, so as to be saturated with it, peculiar neutral  
 salts are produced by it. From the saturation of salt of wood-sorrel with mineral  
 alkali, Wenzel obtained a few small crystals only, resembling alum. The greater  
 part of them shot up perpendicularly into the air, from the sides of the vessel, and  
 preserved indeed their form in the air, but were easily dissolved in water. So that  
 in this salt two different kinds of alkali were combined with the acid. Three hun-  
 dred and seventy-seven grains of salt of sorrel still saturated two drachms of very  
 dry mineral alkali with the redundant acid it contained. Salt of sorrel saturated  
 with the ordinary fixed alkali produced a neutral salt, which according to Wenzel  
 partly concreted in long prismatic crystals; though the greater part of the crystals  
 were composed of large laminae, lying one upon the other, with four, six, and  
 more dissimilar surfaces. Here, no more than two hundred and ninety-four grains  
 of salt of wood-sorrel were requisite for saturating two drams of the ordinary alkali,  
 with the redundant acid contained in them. According to Wiegleb's own expe-  
 riments upon two different sorts of salt of wood-sorrel, half an ounce of one of  
 them took four drams and a half of salt of tartar to saturate it, while the same  
 quantity of the other required no more than three drams and a half. From the  
 former sort he obtained laminated, oblong, rhomboidal crystals, which had con-  
 creted one over the other, almost in the same manner as the salt of sorrel itself.  
 From the latter sort he obtained a neutral salt, of which some of the crystals were  
 extremely small, and cohered together, while others were large, with rhomboidal  
 surfaces, and pretty much resembled borax. These neutral salts precipitate the  
 earth from spring water, and taste almost like crystallized soluble tartar. Salt of  
 sorrel saturated with volatile alkali yields a peculiar salt, in which the pure acid is  
 saturated with the ordinary fixed and the volatile alkali, and which, according to  
 Wenzel, concretes into crystals in shape resembling needles, and does not deli-  
 quescence when exposed to the open air.

Salt of sorrel acts upon various substances without decomposition. With pon-  
 derous earth, magnesia, vegetable alkali, and volatile alkali, it forms triple salts.  
 Lime decomposes it by seizing the whole of the acid, and disengaging the alkali.  
 The attraction of this acid for lime is so strong, that it cannot be disengaged from  
 it by any other acid: another process is therefore necessary to be used for obtain-  
 ing it. With this intention, the superabundant acid is to be saturated with vola-  
 tile alkali; and into this solution must be poured a solution of ponderous earth in  
 the nitrous acid. The last-mentioned acid combines with the alkalis, forming  
 nitrous ammoniac and common nitre, both which remain in solution; while the  
 ponderous earth, combining with the acid of sorrel, forms an insoluble compound  
 which falls to the bottom. This precipitate, after being well washed, may be  
 decomposed by the addition of vitriolic acid, which seizes the earth, and likewise  
 forms an insoluble combination, while the acid is set at liberty. After decantation  
 of the clear liquid, it must be assayed by pouring into it a little at a time of the  
 boiling hot solution of ponderous earth in the acid of sorrel. If there be any  
 excess of vitriolic acid, a precipitate will be formed by its union with the ponderous  
 earth. A due evaporation and cooling of this liquor afford the acid of sorrel in  
 prismatic four-sided crystals or square plates. It is the same acid as that of sugar.  
 See ACID OF SUGAR.

For our knowledge of this salt, and the true nature and method of regenerating

it by art, we are indebted to the immortal Scheele. The analogy of this salt with the acid of sugar induced him to examine it farther; and after a few unsuccessful attempts, he discovered the mode of regenerating it. Having dissolved as much acid of sugar in cold water, as the water could take up, he added to this solution some lixivium of tartar, drop by drop, waiting a little after each drop; and found the mixture, during the effervescence, full of small crystals, which were genuine salt of wood-forrel. The identity of the acid of wood-forrel with that of sugar has not only been proved by Scheele himself, but by several other chemists, particularly Mr. Klaproth of Berlin, by means of a very curious and striking experiment. This gentleman precipitated a solution of quicksilver in nitrous acid, with salt of wood-forrel perfectly neutralized by vegetable alkali, and obtained a white precipitate, which whenedulcorated and dried, and gently heated in a tea-spoon, produced a fulminating noise not inferior to that of fulminating gold. Acid of sugar, perfectly neutralized with vegetable alkali, afforded the same precipitate, and exhibited the same fulminating power. Hence they are now very properly confounded together.

**SOUP.** See **GELLY**.

**SPAR.** Naturalists and chemists have given this name to certain crystallized stones, more or less transparent, which generally do not strike fire with steel, and which are found plentifully within the earth, but more especially in mines of metals.

Under this general name many stones are comprehended; because they have the general properties we have mentioned, and because they resemble each other by the form of their crystallization, in which we always perceive shining plates, like mirrors; but some of these stones are very different from others.

Some spars are entirely soluble with effervescence in acids, forming selenites with vitriolic acid, deliquescent salts with nitrous and marine acids, and being convertible into quick-lime by calcination. These stones are justly called calcareous spars. They consist of lime and fixed air.

Others, although entirely similar to these in appearance, do not effervesce with acids, are calcinable as gypsum and selenites are, and are in fact true selenites composed of vitriolic acid and calcareous earths. These spars are essentially different from the former, and are gypseous or selenitic spars. They consist of lime and vitriolic acid.

Other spars are neither calcareous nor selenitic, do not lose their transparency in the fire, and seem to be of the nature of talc. See the article. The word spar is seldom applied to talcs at present.

Lastly, a kind of stone, crystallized in mirror-like plates, like a true spar, almost opaque, indissoluble by acids, and so much harder than all other spars as to be capable of striking fire with steel. This stone is fusible without addition, by the action of a violent fire, into a semi-transparent white matter. It seems to be the kind that Wallerius, Pott, and other German authors, call fusible spars. They also mention another spar, which is compact, breaks like glass, and melts without addition.

From the descriptions given by most authors, we cannot easily discover what they mean by fusible spar, and by quartz-spar. These matters have not yet been sufficiently examined.

From the properties of all the substances called spars, it may be inferred that they are stones of all kinds, very different from each other, which being formed in metallic grounds, have contracted, either by the mixture of some metallic

earths,



earths, or otherwise, some properties common to all, or, at least, to the greatest number.

These properties enumerated by Macquer are, 1. A certain form of shining laminae in their crystallization, which appears even in those the figure of whose crystals seems least disposed to receive this form, as in those which are striated; for sparry laminae are distinguishable at the extremities of the striæ, or bundles of striæ, of which these spars are composed.

2. A greater specific gravity than of other stones. Some spars, especially those called heavy spars, are so very heavy, that they come near in this respect to metals.

3. A greater fusibility than of other stones; for, besides these spars which are fusible without addition, the mixture of spars facilitates the fusion of most other earths and stones, and they are accordingly used as fluxes in the smelting of most metallic ores. Probably for this reason, these stones have been called fluors by many mineralogists and metallurgists.

Lastly, many spars are found coloured by metallic matters, and resemble the several precious stones, though they are less beautiful and vivid.

To the above passages of Macquer his annotator adds the following, which I have altered in a few places.

The name of spar is given to many stones of different properties and appearances, which do not possess constantly any one common character or mark by which they may be certainly distinguished from other stones. In general, we may observe, that they are most frequently found in mines, and that they for the most part consist of smooth and shining plates or laminae; that some are transparent, and others opaque; that some are colourless, and others are coloured; that they are crystallized in various determinate figures, or possess no determinate shape; and lastly, that they differ so much in hardness, density, degree of fusibility, and in their most essential chemical properties, that they cannot be considered as forming a distinct class of fossil substances. We need not wonder therefore, that authors, especially those who have not been much accustomed to the examination of fossil bodies, should have given very confused and indistinct descriptions of spars. Many of them have not been sufficiently examined; but those of which we have acquired some knowledge we shall endeavour to distinguish into their several different kinds.

The several stones to which the name of spar has been given are, the calcareous, the ponderous, the gypseous, the fluors, and felt spar.

1. Calcareous spars are soft, heavy stones, which have the common chemical properties of calcareous earth. Their texture is laminated. Some of them have no determinate figure, and others from their form are called rhomboidal. Some spars, called dog's-tooth-spar, have a pyramidal figure; but when these are broken, their fragments shew that they also consist of rhomboidal particles.

Some rhomboidal spars are transparent, others are opaque; some are colourless, and others are coloured; lastly, some of them have a singular property of refracting doubly the rays of light which pass through them, and thereby of representing any object; as for instance, the letters of a book, seen through it, double. This spar has been called island crystal, or refracting spar. Its figure is that of an oblique paralleliped, contained within six parallelogrammic sides, and eight solid angles. Each of the obtuse angles of the parallelograms is 101 degrees and 52 minutes; and each of the acute angles is 78 degrees and 8 minutes.

minutes. These are the dimensions given by Sir Isaac Newton of the angles of the sides of the refracting spar.

Calcareous spars may be distinguished from others by effervescing with acids.

2. Gypseous or selenitic spars. These are vitriolated lime, distinctly crystallized. The form of the crystals is rhomboidal. They are also called selenites and glacies Marizæ. Sometimes these spars assume other forms.

3. The ponderous spars are compounds of the ponderous earth, either with fixed air or vitriolic acid. The first of these, which was discovered by Dr. Withering, as mentioned under the article EARTH PONDEROUS, usually resembles alum, and affects a fibrous crystallization diverging from a centre. It has the semi-transparency and appearance of alum. The native specimen examined by Dr. Withering contained 20,8 parts of fixed air, 78,6 of ponderous earth, and the remainder the vitriolic ponderous spar, without any water. In this last respect it differs much from the aerated ponderous earth of Bergman, which he obtained by precipitation from its solvent by mild alkali. This contained 28 parts water, 7 fixed air, and 65 ponderous earth. The fixed air of the artificial compound could be expelled by heat. But that of the natural spar adhered so strongly, probably on account of the absence of water, that it underwent fusion rather than part with it. This spar, as well as the vitriolic, is eminently distinguishable by its great specific gravity, which amounts to 4,338, and is emulated by no other unmetallic earth but the adamantine spar, which is very scarce, at least in Europe.

The common ponderous spar, or compound of ponderous earth and vitriolic acid, has been called marmor metallicum, spar-like gypsum, Bononian stone, and baroselenite. It is found with various degrees of transparency, from perfect clearness to opacity. Of the regularly crystallized sort, Mr. Thompson shewed Magellan some fine specimens, and remarked, that it seems to affect the peculiarity of having its crystals laminated, as radiating from a centre: but this radiation seldom amounts to a whole circle. The corners of these flat crystals are truncated, like those of alum, and are thicker in one side than in the other of each parallelogram, so as to fit one another in the arch of the kind of vault they form together; and have some small ones adhering to their sides, like drusen spars, leaving internal angles, as the macles of the French, or the cruciform crystallizations. In several of the crystals presented to me by that active cultivator of the sciences, the general outline was that of a right-angled parallelogram, and the principal truncatures, namely of the corners, formed angles of 45 degrees. The internal fissures, which resembled those of the common calcareous spar, have likewise this position with respect to each other; which circumstance joined to that of their great weight appeared to be distinctive criterions of this substance. The specific gravity of these crystals proved to be 4,75.

The opake crystals are either white, or reddish, from a slight admixture of iron.

The opake fawn coloured specimens of vitriolated ponderous earth, known by the name of cauk, are common, and affect the peculiar figure of an assemblage of small convex lenses set together edgeways. This is generally distinguished by the name cristated by mineralogists. Its specific gravity is scarcely inferior to that of the transparent specimens.

4. Fluors. Of the spars called fluors, we have treated under the article Fluor.

5. Adamantine spar. See the article. Dr. Combe shewed me a piece of stone



from the East-Indies, of remarkable hardness, supposed to be used in polishing jewels. Its whole figure was such as art had left it. Two sides were flat, apparently from having been sawed with diamond dust. It had the appearance of being part of a larger plate. Its thickness was about a quarter of an inch, the flat sides were unpolished; but a number of small spherical polished concavities had been made in those surfaces, for some use about which I received no information. Its colour was of a dark green, like bottle-glass, so dark as to appear almost opaque. When held to the light, some cloudy striae streaks were seen within it, resembling those of certain spars, and some agates. It had one shake or flaw across the direction of the parallel streaks, and on the whole was evidently a natural production. It very easily marked agate, quartz and other hard stones, and is said to yield in hardness only to the diamond, which I found scratched it without any difficulty. Its weight was 89,2 grains, and it lost by immersion in water 22,25 grains. Whence its specific gravity is deduced 4,09.

**SPECIFIC GRAVITY.** See **GRAVITY SPECIFIC.**

**SPECULARIS LAPIS**, a name occasionally given to the clear vitriolated lime, or gypseous spar.

**SPECULUM.** When tin is melted with copper, it composes the compound called bronze. In this metal the specific gravity is always greater than would be deduced by computation from the quantities and specific gravities of its component parts. The uses of this hard, sonorous, and durable composition, in the fabrication of cannon, bells, statues, and other articles, are well known. Bronzes and bell-metals are not usually made of copper and tin only, but have other admixtures, consisting of lead, zinc, or arsenic, according to the motives of profit, or other inducements of the artist. But the attention of the philosopher is more particularly directed to the mixture of copper and tin, on account of its being the substance of which the speculums of reflecting telescopes are made. The metal required for this purpose ought to be capable of an exquisite polish, hard enough to receive and retain a figure accurately suited to the regular reflection of light, and not subject to become tarnished by the action of the atmosphere. Many excellent telescopes have been made with compositions of pure copper, alloyed with somewhat less than half its weight of tin. But it appears to be very well ascertained, from the observations of the astronomer royal, that the speculums of Mr. Edwards, whose composition was the result of numerous trials, are much superior to any which have yet been made, and are even equal in light to acromatic telescopes of the same aperture, without altering the colours of objects. He first melts 32 parts of copper as fluid as possible, with one part of brass, and one of silver, together with the black flux; at the same time that 15 parts of tin are melted in a separate crucible. These being taken from the fire, he pours the tin to the copper; immediately stirs the whole together with a wooden spatula, and pours it out hastily into a large quantity of cold water, which cools and granulates the composition. If the tin were fused together with the copper, or if they were to remain for any length of time in the extreme heat which is necessary to fuse this last metal, a part of the tin would be calcined, and the metal would abound more or less with small microscopic pores. If one of the pieces of the cold metal be broken, it will appear of a most beautiful bright colour, resembling quicksilver. Mr. Edwards affirms, that different kinds of copper require different doses of tin to produce the most perfect whiteness. If the dose of tin be too small, which is the fault most easily remedied, the composition will be yellowish; if it be too great, the composition will

will be of a gray blue colour, and dull appearance. He therefore finds by trial the quantity of tin necessary to be added in the second fusion to render the metal the most perfect. A much less degree of heat is then required to melt the compound. In the second melting he adds one part of arsenic, and immediately stirs the mixture; which he pours into the mould as soon as the fumes of the arsenic have ceased to rise. He casts the speculum in sand, with the face downwards, takes it out while red-hot, and places it in hot wood ashes to cool; without which precaution it would break in cooling.

As the construction of telescopes is foreign to the immediate purpose of this work, it has not been thought necessary to mention the several precautions of Mr. Edwards in this business; but the curious operator, who may wish to undertake the construction of a reflecting telescope (the better kinds of which are not only difficult to be procured, but of considerable price), may have recourse to Edwards's treatise, annexed to the Nautical Almanack for 1787; where he will find ample instructions for that purpose.

The composition of metal for speculums, previous to the invention of the reflecting telescope, was in the hands of artists, and did not require that extreme perfection with regard to density and other properties, which the specula of those instruments demand. Experience shewed them that arsenic is a valuable ingredient in these mixtures; but speculative philosophers, reasoning from the saline property of that substance before it was known that it can be reduced to a metallie regulus, were apprehensive that it would increase the disposition to tarnish. I conjecture that Mr. Edwards's composition might be improved by a greater proportion of arsenic, or at least by adding this ingredient in an earlier stage of the process. For this reason, I shall here insert the directions which Blancourt in his Art of Glass gives, as the best of all compositions for whiteness, hardness, and susceptibility of an exceeding fine polish. As I do not answer for the value of this receipt, I shall give it in the author's own words, after remarking that the oil of tartar is evidently unnecessary; that the gradual management of the heat on a sand bath, is probably a useless refinement; that the substitution of orpiment for arsenic, as he recommends, must be noxious; that by latten I understand common brass, of which there are various kinds; and that the addition of the tin should be made in the fused state.

Take plates of copper, one pound, mince them that they may be put into a crucible, imbibing them with oil of tartar; then powder a quarter of a pound of white arsenic, and put these S. S. S. as we have shewn the method elsewhere, until you fill the crucible; pour on them afterwards linseed-oil to cover the arsenic and the copper; head and lute your crucible; and when the lute is dry, set it on a sand furnace, letting the sand arise no higher than the head; heat the furnace gently till it arrive at a just degree, and the oil begins to evaporate; by this time the oil will prepare the copper for retaining the arsenic, which must enter the copper as easily as oil does leather; set it again on fresh sand, and increase the heat of the furnace, giving it the same degree as before, until the oil evaporate and boil up; then take off the crucible, let it cool, and break it, you will find your copper of several colours, and would be much better, if instead of arsenic you made use of orpiment.

Take of this copper one part, of latten two parts, melt the latten on a smart fire, and so put in the copper; when they are well melted, cast the metal drop

English Translation, London 1699.



by drop into a glazed earthen vessel full of water, over which lay a bush or broom for the stuff to go through; thus you will have a metal not to be touched with a file, nor brittle, as good as any steel for all uses whatsoever.

Take of this hard metal, three parts, and best tin of Cornwall, which has no lead in it, one part; melt the metal before you put in the tin; after these are well incorporated, you may fill your moulds, &c.

**SPEISS.** The Bohemian name for mispickel, which see.

**SPELTER.** Zinc is called spelter in commerce. The soft brass containing a redundant proportion of zinc, and sold in the granulated form for the use of artists in foldering, is called spelter folder, and frequently spelter only.

**SPERMACEI.** The brain of a species of whale, purified from the oily matter, affords a fat of a singular kind, known in the shops by the improper name of spermaceti.

The spermaceti whale, called *cetus dentatus*, and orca, and by the English sailors employed in the Greenland-fishery, torump, jubart, or gibbart, is smaller than the common whale, but the head is proportionably much larger, amounting to above one-third the bulk of the whole body. He is furnished with teeth, which the other is not; and wants the flexible bones in the mouth, called whale-bone, which the other has. The throat is also remarkably wider.

One of these fishes affords some tons of brains, which are first grossly freed from the oil by draining and pressing, and afterwards more perfectly purified by steeping them in a ley of alkaline salt and quick-lime, which dissolves the remains of the oily matter into a saponaceous liquid. The brains, being then washed with water, appear of a silver whiteness; and nothing more is required to complete the preparation than to cut them in shivers with wooden knives, and spreading them abroad to dry. Such is the simple process, by which this profitable commodity is prepared. It has been said that spermaceti is a natural concrete, found floating on the surface of the northern seas; but this is plainly a false report, perhaps calculated to prevent enquiry into the manner of its preparation.

Good spermaceti is in fine white flakes, glossy and semi-transparent, soft and unctuous to the touch, yet dry and easily friable, in taste somewhat like butter, of a faint smell like that of tallow.

It is apt in keeping, if not carefully secured from the air, to grow yellowish, and contract a rancid fishy smell. The more perfectly it has been purified at first, the less susceptible it is of these alterations; and after it has been so changed, it may be reduced white and sweet again, by steeping it afresh in a ley of alkaline salt and quick-lime.

It melts in a small degree of heat, and congeals again as it cools. Laid on burning coals, it emits a fetid smell, like that of the snuff of a candle. The contact of flame does not set it on fire, but with a wick it burns equally with common tallow-candles.

In distillation it totally arises, leaving no coal or caput mortuum behind; from four ounces were obtained three ounces and a half of oil, and a dram and a half of phlegm; the other two drams and a half having been wasted or dissipated in the process. The oil is not a brown or black fetid empyreumatic one, like those of other animal substances; but clear, yellowish, of a butyraceous consistence, in smell like oil of wax, like which also it coagulates in the cold.

Rectified spirit of wine, digested and boiled with spermaceti, takes up about half a dram out of half an ounce; the greatest part settles to the bottom, and the

the finer particles float in the liquor, in appearance like flowers of benzoin.

Water long digested or boiled with it extracts nothing. By grinding it with sugar or almonds, it becomes miscible with water, but not near so perfectly as the vegetable resins do by the same treatment; on standing for a little time, the spermaceti separates and floats on the surface. Yolks of eggs unite it more thoroughly with watery liquors: but when dissolved by these also, it soon separates and falls to the bottom.

Even caustic alkaline ley does not dissolve nor unite with it into soap, as it does with all other fats; and hence the use of this ley in its preparation and purification. It mingles sufficiently with oils, fats, balsams, resins, butter, wax, &c.

It has been conjectured that this singular substance bears the same relation to fat oils as camphor does to the essential oils. Wax appears to have the same relation to fixed oils as resin has to the essential; that is to say, both have been rendered concrete by the absorption of vital air. But spermaceti and camphor seem to differ in some other leading particular; probably in the absence of acid, or of any basis which can easily be acidified by the action of nitrous or other acids. Much information would no doubt be derived from a careful examination of the products which these several substances afford by combustion.

Excellent candles are made from spermaceti, in those places where it is prepared, at Bayonne, at St. Jean-de-Luz, &c. In England there are many manufactories of these candles; and within these few years some such have been established at Paris.

Spermaceti appears to be a medium between wax and tallow, with respect to the advantages derived from it with a thin wick. See LIGHT.

The nitrous and the muriatic acids are incapable of acting on this substance. The concentrated sulphuric acid dissolves it, and at the same time alters its colour: this solution is precipitated by water, like oil of camphor.

It combines with sulphur like fixed oils. Hot alcohol dissolves it as well as fixed and volatile oils, but suffers it to precipitate by cooling. Ether effects this solution cold, or at least without the help of a greater heat than the natural warmth of the hand.

The attention of chemists has been greatly excited by the spontaneous conversion of animal matter into a substance of the same nature as spermaceti. The fact has long been well known, and is said to have been mentioned in the works of Lord Bacon, though I have not seen the passage. On the occasion of the removal of a very great number of human bodies from the ancient burying-place Des Innocens at Paris, facts of this nature were observed in the most striking manner. M. De Fourcroy may be called the scientific discoverer of this peculiar matter, as well as the saponaceous ammoniacal substance contained in bodies abandoned to spontaneous destruction in large masses. This chemist read a Memoir on the subject in the year 1789 to the Royal Academy of Sciences, from which I shall abstract the general contents\*.

At the time of clearing the before mentioned burying-place, certain philosophers were specially charged to direct the precautions requisite for securing the health of the workmen. A new and singular object of research presented itself, which had been necessarily unknown to preceding chemists. It was impossible to foretell what might be the contents of a soil overloaded for successive ages

\* Annales du Chimie, v. 154.

with



with bodies resigned to the putrefactive process. This spot differed from common burying-grounds, where each individual object is surrounded by a portion of the soil. It was the burying-ground of a large district, wherein successive generations of the inhabitants had been deposited for upwards of three centuries. It could not be foreseen that the entire decomposition might be retarded for more than forty years; neither was there any reason to suspect that any remarkable difference would arise from the singularity of situation.

The remains of the human bodies immersed in this mass of putrescence were found in three different states, according to the time they had been buried, the place they occupied, and their relative situations with regard to each other. The most ancient were simply portions of bones, irregularly dispersed in the soil, which had been frequently disturbed. A second state, in certain bodies which had always been insulated, exhibited the skin, the muscles, tendons and aponeuroses, dry, brittle, hard, more or less gray, and similar to what are called mummies in certain caverns where this change has been observed, as in the catacombs at Rome, and the vault of the Cordeliers at Toulouse.

The third and most singular state of these soft parts was observed in the bodies which fill the common graves or repositories. By this appellation are understood cavities of thirty feet in depth and twenty on each side, which were dug in the burying-ground of the Innocents, and were appropriated to contain the bodies of the poor; which were placed in very close rows, each in its proper wooden bier. The necessity for disposing a great number obliged the men charged with this employment to arrange them so near each other, that these cavities might be considered when filled as an entire mass of human bodies, separated only by two planks of about half an inch thick. Each cavity contained between one thousand and fifteen hundred. When one common grave of this magnitude was filled, a covering of about one foot deep of earth was laid upon it, and another excavation of the same sort was made at some distance. Each grave remained open about three years, which was the time required to fill it. According to the urgency of circumstances, the graves were again made on the same spot after an interval of time not less than fifteen years, nor more than thirty. Experience had taught the workmen that this time was not sufficient for the entire destruction of the bodies, and had shewn them the progressive changes which form the object of M. Fourcroy's Memoir.

The first of these large graves opened in the presence of this chemist had been closed for fifteen years. The biers or coffins were in good preservation, but a little settled, and the wood (I suppose deal) had a yellow tinge. When the covers of several were taken off, the bodies were observed at the bottom, leaving a considerable distance between their surface and the cover, and flattened as if they had suffered a strong compression. The linen which had covered them was slightly adherent to the bodies; and, with the form of the different regions, exhibited on removing the linen nothing but irregular masses of a soft ductile matter of a gray white colour. These masses environed the bones on all sides, which had no solidity, but broke by any sudden pressure. The appearance of this matter, its obvious composition and its softness, resembled common white cheese; and the resemblance was more striking from the print which the threads of the linen had made upon its surface. This white substance yielded to the touch, and became soft when rubbed for a time between the fingers.

No very offensive smell was emitted from these bodies. The novelty and singularity of the spectacle, and the example of the grave-diggers, dispelled every idea

idea either of disgust or apprehension. These men asserted that they never found this matter, by them called *gras* (fat), in bodies interred alone; but that the accumulated bodies of the common graves only were subject to this change. On a very attentive examination of a number of bodies passed to this state, M. Fourcroy remarked that the conversion appeared in different stages of advancement; so that, in various bodies, the fibrous texture and colour, more or less red, were discernible within the fatty matter; that the masses covering the bones were entirely of the same nature, offering indistinctly in all the regions a gray substance for the most part soft and ductile, sometimes dry, always easy to be separated in porous fragments, penetrated with cavities, and no longer exhibiting any traces of membranes, muscles, tendons, vessels, or nerves. On the first inspection of these white masses, it might have been concluded that they were simply the cellular tissue, the compartments and vesicles of which they very well represented.

By examining this substance in the different regions of the body, it was found that the skin is particularly disposed to this remarkable alteration. It was afterwards perceived that the ligaments and tendons no longer existed, or at least had lost their tenacity; so that the bones were entirely unsupported, and left to the action of their own weight. Whence their relative places were preserved in a certain degree by mere juxtaposition; the least effort being sufficient to separate them. The grave-diggers availed themselves of this circumstance in the removal of the bodies. For they rolled them up from head to feet, and by that means separated from each other the extremities of the bones which had formerly been articulated. In all these bodies which were changed into the fatty matter the abdominal cavity had disappeared. The teguments and muscles of this region being converted into the white matter like the other soft parts, had subsided upon the vertebral column, and were so flattened as to leave no place for the viscera, and accordingly there was scarcely ever any trace observed in the almost obliterated cavity. This observation was for a long time matter of astonishment to the investigators. In vain did they seek in the greater number of bodies the place and substance of the stomach, the intestines, the bladder, and even the liver, the spleen, the kidneys, and the matrix in females. All these viscera were confounded together, and for the most part no traces of them were left. Sometimes only certain irregular masses were found, of the same nature as the white matter, of different bulks, from that of a nut to two or three inches in diameter, in the regions of the liver or of the spleen.

The thorax likewise offered an assemblage of facts no less singular and interesting. The external part of this cavity was flattened and compressed like the rest of the organs; the ribs, spontaneously luxated in their articulations with the vertebræ, were settled upon the dorsal column; their arched part left only a small space on each side between them and the vertebræ. The pleura, the mediastines, the large vessels, the aspera arteria, and even the lungs and the heart, were no longer distinguishable; but for the most part had entirely disappeared, and in their place nothing was seen but some parcels of the fatty substance. In this case, the matter which was the product of decomposition of the viscera, charged with blood and various humours, differs from that of the surface of the body, and the long bones, in the red or brown colour possessed by the former. Sometimes the observers found in the thorax a mass irregularly rounded of the same nature as the latter, which appeared to them to have arisen from the fat and fibrous substance of the heart. They supposed that this mass, not constantly found in all the subjects, owed its existence to a superabundance of fat in this viscus,



viscus, where it was found. For the general observation presented itself, that in similar circumstances, the fat parts undergo this conversion more evidently than the others, and afford a larger quantity of the white matter.

The external region in females exhibited the glandular and adipose mass of the breasts converted into the fatty matter very white and very homogeneous.

The head was, as has already been remarked, environed with the fatty matter; the face was no longer distinguishable in the greatest number of subjects; the mouth disorganized exhibited neither tongue nor palate, and the jaws, luxated and more or less displaced, were environed with irregular layers of the white matter. Some pieces of the same matter usually occupied the place of the parts situated in the mouth; the cartilages of the nose participated in the general alteration of the skin; the orbits instead of eyes contained white masses; the ears were equally disorganized; and the hairy scalp having undergone a similar alteration to that of the other organs, still retained the hair. M. Fourcroy remarks incidentally that the hair appears to resist every alteration much longer than any other part of the body. The cranium constantly contained the brain contracted in bulk; blackish at the surface, and absolutely changed like the other organs. In a great number of subjects which were examined this viscus was never found wanting, and it was always in the above-mentioned state; which proves that the substance of the brain is greatly disposed to be converted into the fat matter.

Such was the state of the bodies found in the burial ground Des Innocens. Its modifications were also various. Its consistence in bodies lately changed, that is to say, from three to five years, was soft and very ductile; containing a great quantity of water. In other subjects converted into this matter for a long time, such as those which occupied the cavities which had been closed thirty or forty years, this matter is drier, more brittle and in denser flakes. In several which were deposited in dry earth, various portions of the fatty matter had become semi-transparent. The aspect, the granulated texture, and brittleness of this dried matter, bore a considerable resemblance to wax.

The period of the formation of this substance had likewise an influence on its properties. In general, all that which had been formed for a long time was white, uniform, and contained no foreign substance, nor fibrous remains; such in particular was that afforded by the skin of the extremities. On the contrary, in bodies recently changed, the fatty matter was neither so uniform nor so pure as in the former; but it was still found to contain portions of muscles, tendons, and ligaments, the texture of which, though already altered and changed in its colour, was still distinguishable. Accordingly, as the conversion was more or less advanced, these fibrous remains were more or less penetrated with the fatty matter, interposed as it were between the intestices of the fibres. This observation shews that it is not merely the fat which is thus changed, as was natural enough to think at first sight. Other facts confirm this assertion. The skin, as has been remarked, becomes easily converted into very pure white matter, as does likewise the brain, neither of which have been considered by anatomists to be fat. It is true nevertheless, that the unguinous parts, and bodies charged with fat, appear more easily and speedily to pass to the state under consideration. This was seen in the marrow, which occupied the cavities of the longer bones. And again, it is not to be supposed, but that the greater part of these bodies had been emaciated by the illness which terminated their lives; notwithstanding which, they were all absolutely turned into this fatty substance.

An experiment made by M. Poulletier De la Salle and Fourcroy likewise evinced that a conversion does not take place in the fat alone. M. Poulletier had suspended in his laboratory a small piece of the human liver, to observe what would arise to it by the contact of the air. It partly putrefied, without however emitting any very infectious smell. Larvæ of the *Dermestes*, and *Bruches* attacked and penetrated it in various directions; at last it became dry, and after more than ten years suspension, it was converted into a white friable substance resembling dried agaric, which might have been taken for an earthy substance. In this state, it had no perceptible smell. M. Poulletier was desirous of knowing the state of this animal matter, and experiment soon convinced him and M. F. that it was very far from being in the state of an earth. It melted by heat, and exhaled in the form of vapour, which had the smell of a very fetid fat; spirit of wine separated a concrescible oil which appeared to possess all the properties of spermaceti. Each of the three alkalis converted it into soap, and in a word it exhibited all the properties of the fatty matter of the burial-ground of the Innocens exposed for several months to the air. Here then was a glandular organ, which in the midst of the atmosphere had undergone a change similar to that of the bodies in the burying-place; and this fact sufficiently shews that an animal substance which is very far from being of the nature of grease may be totally converted into this fatty substance.

Among the modifications of this remarkable substance in the burying ground before mentioned, it was observed that the dry, friable, and brittle matter was most commonly found near the surface of the earth, and the soft ductile matter at a greater depth. M. Fourcroy remarks, that this dry matter did not differ from the other merely in containing less water, but likewise by the volatilization of one of its principles. He promises to explain this difference in another memoir, which, if published, I have not seen.

The grave diggers assert that near three years are required to convert a body into this fatty substance. But Mr. Gibbes, in the *Philosophical Transactions* for 1794, found that lean beef secured in a running stream was converted into this fatty matter at the end of a month. He judges from facts, that running water is most favourable to this process. He took three lean pieces of mutton, and poured on each a quantity of the three ancient mineral acids. At the end of three days, each was much changed: that in the nitrous acid was very soft, and converted into the fatty matter; that in the marine acid was not in that time so much altered; the vitriolic acid had turned the other black. M. Lavoisier, in his *Elements of Chemistry*, thinks that this process may hereafter prove of great use in society. It is not easy to point out what animal substance, or what situation, might be the best adapted for an undertaking of this kind. M. L. points out fecal matters; but I have not heard of any conversion having taken place in these animal remains, similar to that of the foregoing.

The result of M. Fourcroy's enquiries into the ordinary changes of bodies recently deposited in the earth was not very extensive. The grave-diggers informed him, that these bodies interred do not perceptibly change colour for the first seven or eight days; that the putrid process disengages elastic fluid which inflates the abdomen, and at length bursts it; that this event instantly causes vertigo, faintness, and nausea in such persons as unfortunately are within a certain distance of the scene where it takes place; but that when the object of



its action is nearer, a sudden privation of sense, and frequently death is the consequence. These men are taught by experience, that no immediate danger is to be feared from the disgusting business they are engaged in, excepting at this period, which they regard with the utmost terror. They resisted every inducement and persuasion which these philosophers made use of to prevail on them to assist their researches into the nature of this active and pernicious vapour. M. Fourcroy takes occasion from these facts, as well as from the pallid and unwholesome appearance of the grave-diggers, to reprobate burials in great towns or their vicinity.

Such bodies as are interred alone in the midst of a great quantity of humid earth, are totally destroyed by passing through the successive degrees of the ordinary putrefaction; and this destruction is more speedy, the warmer the temperature. But if these insulated bodies be dry and emaciated; if the place of deposition be likewise dry, and the locality and other circumstances such, that the earth, so far from receiving moisture from the atmosphere, becomes still more effectually parched by the solar rays, — the animal juices are volatilized and absorbed, the solids contract and harden, and a peculiar species of mummy is produced. But every circumstance is very different in the common burying-grounds. Heaped together almost in contact, the influence of external bodies affects them scarcely at all, and they become abandoned to a peculiar disorganization which destroys their texture, and produces the new and most permanent state of combination here described. From various observations which I do not here abridge, it was found that this fatty matter was capable of enduring in these burying-places for thirty or forty years, and is at length corroded and carried off by the aqueous putrid humidity which there abounds.

**SPIKENARD.** *Nardus Indica*, quæ spica, spica nardi et spica Indica officinarum C. B. *Andropogon nardus* Lin. Indian nard brought from the East Indies.

It consists of a number of slender brittle filaments, supposed by some to be the root, by others the pedicle of the leaves of a plant of the grass or rush kind; but which are properly the head of a root, for Pomet mentions and figures a specimen which had great part of the root itself adhering.

Spikenard has a very strong, not agreeable smell and taste, scarce to be concealed or overpowered by a large admixture of other substances. It contains only a small proportion of essential oil: on distilling an ounce, there was only an appearance of some oily particles on the surface of the water. Rectified spirit brings over nothing: the spirituous extract possesses both the smell and taste of the spikenard in a much greater degree than the watery. An ounce yielded a dram of spirituous, and afterwards forty-six grains of watery extract. Water applied at first extracted from the same quantity four scruples, and spirit afterwards twenty-five grains: the indissoluble residuum weighed in both cases six drams ten grains. Neumann.

**SPIRIT.** This name was formerly given by chemists to all volatile substances collected by distillation. Three principal kinds were distinguished; namely, inflammable or ardent spirits, acid spirits, and alkaline spirits. In the first class were included, not only the product known by the common name of spirit of wine, but also the light volatile oils, ethers, and the aromatic principles. The contents of the latter classes need no enumeration.

The word spirit is now almost exclusively confined to alcohol, ardent spirit, or spirit of wine; and the other substances formerly arranged under the classes here mentioned,

mentioned, are distinguished by their respective peculiar names, without reference to any general arrangement grounded on a property of so indistinct a nature as that of their being separated from other compounds by distillation.

**SPIRIT, ARDENT.** In order to obtain ardent spirit, nothing more is necessary than to expose wine, beer, or any other fermented vinous liquid, to distillation; and the product which comes over is the ardent spirit itself, contaminated with essential oil. If this be rectified by a second distillation, it becomes much purer. The most volatile part rises first, and is of a less specific gravity than that which comes over afterwards.

The residue, after the distillation of ardent spirit from wine, is of a deep colour, a rough acid taste, and deposits crystals of tartar. The colouring matter is soluble in ardent spirit. So that it appears, from this imperfect analysis, that wine consists of water, ardent spirit, colouring matter of a resinous nature, sugar, tartar, and tartareous acid, and an aromatic principle.

The strength or purity of ardent spirit is ascertained from its specific gravity; for the addition of water renders it heavier. According to M. Bories, whose Memoir, published at Montpellier in the year 1774, obtained the prize proposed by the states of Languedoc in 1772, the specific gravity of rectified ardent spirit, repeatedly poured on dry salt of tartar till it would no longer dissolve or liquefy it, was found by many experiments to be as follows:

Reaumur's Therm.  $+ 10^{\circ} = 820$   
 $+ 15^{\circ} = 817$   
 $+ 20^{\circ} = 813$

The specific gravities of mixtures, by measure, of the foregoing spirit with distilled water, were as follows:

Temperature $+ 15^{\circ}$ Reaumur.			
Spirit	10	Water	0
	0	1	Specific gravity 817
	9	1	844
	8	2	869
	7	3	893
	6	4	915
	5	5	934
	4	6	951
	3	7	965
	2	8	976
	1	9	987
	0	10	1,000

Upon the above experiments, which are among the most accurate we possess, it may be observed, that the first term, or pure spirit, ought to be obtained with an alkali perfectly mild, or saturated with fixed air; because, otherwise, solution and combination of the alkali with the spirit might take place. By distillation of twenty measures of the best ardent spirit of the shops, whose specific gravity was 0.836 over a lamp in glass vessels, I found the first measure which came over had a specific gravity of 820, at the temperature of  $71^{\circ}$  Fahrenheit; which answers to  $17\frac{1}{2}$  of Reaumur. This is the strongest spirit mere distillation can afford. When strong ardent spirit is added to water, a considerable heat is produced, a few bubbles of air are emitted, the mixture contracts in its di-



mentions, and acquires a greater specific gravity than would have been deduced by computation.

It is by no means an easy undertaking to determine the strength or relative value of ardent spirit, even with sufficient accuracy for commercial purposes. The following requisites must be obtained before this can be well done: The specific gravity of a certain number of mixtures of ardent spirit and water must be taken so near each other, as that the intermediate specific gravities may not perceptibly differ from those deduced from the supposition of a mere mixture of the fluids: the expansions or variations of specific gravity in these mixtures, must be determined at different temperatures: some easy method must be contrived of determining the presence and quantity of saccharine or oleaginous matter which the spirit may hold in solution, and the effect of such solution on the specific gravity: and lastly, the specific gravity of the fluid must be ascertained by a proper floating instrument with a graduated stem, or set of weights; or, which may be more convenient, with both.

The strength of brandies in commerce is judged by the phial, or by burning. The phial proof consists in agitating the spirit in a bottle, and observing the form and magnitude of the bubbles, which are larger the stronger the spirit. These probably depend on the solution of resinous matter from the cask, which is taken up in greater quantities, the stronger the spirit. It is not difficult however to produce this appearance by various simple additions to weak spirit. The proof by burning is also fallacious; because the magnitude of the flame, and quantity of residue, in the same spirit, vary greatly with the form of the vessel it is burned in. If the vessel be kept cool, or suffered to become hot, if it be deeper or shallower, the results will not be the same in each case. It does not follow, however, but that manufacturers and others may in many instances receive considerable information from these signs, in circumstances exactly alike, and in the course of operations wherein it would be inconvenient to recur continually to experiments of specific gravity.

The importance of this object, as well for the purposes of revenue as of commerce, induced the British government to employ Dr. Blagden to institute a very minute and accurate series of experiments. These may be considered as fundamental results; for which reason, I shall insert the whole in this place, from the Philosophical Transactions for 1790, in the words of the author.

The first object to which the experiments were directed, was to ascertain the quantity and law resulting from the mutual penetration of water and spirit.

All bodies in general expand by heat; but the quantity of this expansion, as well as the law of its progression, is probably not the same in any two substances. In water and spirit they are remarkably different. The whole expansion of pure spirit from  $30^{\circ}$  to  $100^{\circ}$  of Fahrenheit's thermometer, is not less than  $\frac{1}{3}$  of its whole bulk at  $30^{\circ}$ ; whereas that of water, in the same interval, is only  $\frac{1}{11}$  of its bulk. The laws of their expansion are still more different than the quantities. If the expansion of quicksilver be, as usual, taken for the standard (our thermometers being constructed with that fluid), the expansion of spirit is, indeed, progressively increasing with respect to that standard, but not much so within the above-mentioned interval; whilst water kept from freezing to  $30^{\circ}$ , which may easily be done, will absolutely contract as it is heated for ten or more degrees, that is, to  $40^{\circ}$  or  $42^{\circ}$  of the thermometer, and will then begin to expand as its heat is augmented, at first slowly, and afterwards gradually more

more rapidly, so as to observe upon the whole a very increasing progression. Now, mixtures of these two substances will, as may be supposed, approach to the less or the greater of these progressions, according as they are compounded of more spirit or more water, whilst their total expansion will be greater, according as more spirit enters into their composition; but the exact quantity of the expansion, as well as law of the progression, in all of them, can be determined only by trials. These were, therefore, the two other principal objects to be ascertained by experiment.

The first step towards a right performance of the experiments was to procure the two substances with which they were to be made as pure as possible. Distilled water is in all cases so nearly alike, that no difficulty occurred with regard to it; but the specific gravity of pure spirit, or alcohol, has been given so very differently by the authors who have treated of it, that a particular set of experiments appeared necessary for determining to what degree of strength rectified spirits could conveniently be brought. The person engaged to make these experiments was Dr. Dollfus, an ingenious Swiss gentleman then in London, who had distinguished himself by several publications on chemical subjects. Dr. Dollfus, having been furnished by government with spirit for the purpose, rectified it by repeated and slow distillations till its specific gravity became stationary in this manner of operating: he then added dry caustic alkali to it, let it stand for a few days, poured off the liquor, and distilled it with a small addition of burnt alum, placing the receiver in ice. By this method he obtained a spirit whose specific gravity was .8188 at 60° of heat. Perceiving however that he could not conveniently get the quantity of spirit he wanted lighter than .82527 at 60°, he fixed upon that strength as a standard, to which he found the above-mentioned lighter spirit could be reduced by adding to it a  $\frac{1}{221}$  part of water; and with this spirit and distilled water he made a series of experiments for determining the specific gravity of different mixtures of these fluids in different degrees of heat.

The process followed by Dr. Dollfus is not here given as the best possible for obtaining pure spirit; nor was the result of it in fact the lightest alcohol that has been procured. Some spirit has been tried since that time, whose specific gravity was .813 at 60°. This was furnished by Dr. George Fordyce, F. R. S. who succeeded in bringing it to that strength chiefly by adding the alkali very hot. Care must be taken that none of the caustic alkali comes over in the distillation. Some alcohol was also sent for trial, by Mr. Lewis an eminent distiller in Holborn, whose specific gravity at the same temperature was .814.

It was with spirit rectified from malt spirits that Dr. Dollfus's series of experiments was made; but he tried several comparative experiments, with such as had been rectified from rum and brandy, and found no other difference than what might fairly be ascribed to unavoidable errors.

These experiments of Dr. Dollfus were repeated by Mr. Gilpin, clerk of the Royal Society; and as the deductions in this account will be taken chiefly from that last set of experiments, it is proper here to describe minutely the method observed by Mr. Gilpin in his operation. This naturally resolves itself into two parts: the way of making the mixtures, and the way of ascertaining their specific gravity.

1. The mixtures were made by weight, as the only accurate method of fixing the proportions. In fluids of such very unequal expansions by heat as water and alcohol, if measures had been employed, increasing or decreasing in regular

proportions



proportions to each other, the proportions of the masses would have been sensibly irregular; now the latter was the object in view, namely, to determine the real quantity of spirit in any given mixture, abstracting the consideration of its temperature. Besides, if the proportions had been taken by measure, a different mixture should have been made at every different degree of heat. But the principal consideration was, that with a very nice balance, such as was employed on this occasion, quantities can be determined to much greater exactness by weight than by any practicable way of measurement. The proportions were therefore always taken by weight. A phial being provided of such a size as that it should be nearly full with the mixture, was made perfectly clean and dry, and being counterpoised, as much of the pure spirit as appeared necessary was poured into it. The weight of this spirit was then ascertained, and the weight of distilled water required to make a mixture of the intended proportions was calculated. This quantity of water was then added, with all the necessary care, the last portions being put in by means of a well-known instrument, which is composed of a small dish terminating in a tube drawn to a fine point: the top of the dish being covered with the thumb, the liquor in it is prevented from running out through the tube by the pressure of the atmosphere, but instantly begins to issue by drops, or a very small stream, upon raising the thumb. Water being thus introduced into the phial, till it exactly counterpoised the weight, which having been previously computed, was put into the opposite scale, the phial was shaken, and then well stopped with its glass stopple, over which leather was tied very tight, to prevent evaporation. No mixture was used till it had remained in the phial at least a month, for the full penetration to have taken place; and it was always well shaken before it was poured out to have its specific gravity tried.

2. There are two common methods of taking the specific gravity of fluids; one, by finding the weight which a solid body loses by being immersed in them; the other, by filling a convenient vessel with them, and ascertaining the increase of weight it acquires. In both cases a standard must have been previously taken, which is usually distilled water; namely, in the first method by finding the weight lost by the solid body in the water, and in the second method, the weight of the vessel filled with water. The latter was preferred for the following reasons:

When a ball of glass, which is the properest kind of solid body, is weighed in any spirituous or watery fluid, the adhesion of the fluid occasions some inaccuracy, and renders the balance comparatively sluggish. To what degree this effect proceeds is uncertain; but from some experiments made by Mr. Gilpin, with that view, it appears to be very sensible. Moreover, in this method a large surface must be exposed to the air during the operation of weighing, which, especially in the higher temperatures, would give occasion to such an evaporation as to alter essentially the strength of the mixture. It seemed also as if the temperature of the fluid under trial could be determined more exactly in the method of filling a vessel, than in the other; for the fluid cannot well be stirred while the ball to be weighed remains immersed in it; and as some time must necessarily be spent in the weighing, the change of heat which takes place during that period will be unequal through the mass, and may occasion a sensible error. It is true, on the other hand, that, in the method of filling a vessel, the temperature could not be ascertained with the utmost precision, because the neck of the vessel employed, containing about ten grains, was filled up to the

the mark with spirit not exactly of the same temperature, as will be explained presently: but this error, it is supposed, would by no means equal the other, and the utmost quantity of it may be estimated very nearly. Finally, it was much easier to bring the fluid to any given temperature when it was in a vessel to be weighed, than when it was to have a solid body weighed in it; because in the former case the quantity was smaller, and the vessel containing it more manageable, being readily heated with the hand or warm water, and cooled with cold water: and the very circumstance, that so much of the fluid was not required, proved a material convenience. The particular disadvantage in the method of weighing in a vessel, is the difficulty of filling it with extreme accuracy; but when the vessel is judiciously and neatly marked, the error of filling will, with due care, be exceedingly minute. By several repetitions of the same experiments, Mr. Gilpin seemed to bring it within the  $\frac{1}{100}$ th part of the whole weight.

The above-mentioned considerations induced Dr. Blagden, as well as the gentlemen employed in the experiments, to give the preference to weighing the fluid itself; and that was accordingly the method practised both by Dr. Dollfus and Mr. Gilpin in their operations.

The vessel chosen as most convenient for the purpose was a hollow glass ball, terminating in a neck of small bore. That which Dr. Dollfus used held 5800 grains of distilled water; but as the balance was so extremely accurate, it was thought expedient, upon Mr. Gilpin's repetition of the experiments, to use one of only 2965 grains capacity, as admitting the heat of any fluid contained in it to be more nicely determined. The ball of this vessel, which may be called the weighing-bottle, measured about 2.8 inches in diameter, and was spherical, except a slight flattening on the part opposite to the neck, which served as a bottom for it to stand upon. Its neck was formed of a portion of a barometer tube,  $\frac{1}{25}$  of an inch in bore, and about  $1\frac{1}{2}$  inch long; it was perfectly cylindrical, and on its outside, very near the middle of its length, a fine circle or ring was cut round it with a diamond, as the mark to which it was to be filled with the liquor. This mark was made by fixing the bottle in a lathe, and turning it round with great care, in contact with the diamond. The glass of this bottle was not very thick; it weighed 916 grains, and with its silver cap 936.

When the specific gravity of any liquor was to be taken by means of this bottle, the liquor was first brought nearly to the required temperature, and then the bottle was filled with it up to the beginning of the neck only, that there might be room for shaking it. A very fine and sensible thermometer was then passed through the neck of the bottle into the contained liquor, which shewed whether it was above or below the intended temperature. In the former case the bottle was brought into colder air, or even plunged for a moment into cold water; the thermometer in the mean time being frequently put into the contained liquor, till it was found to sink to the right point. In like manner, when the liquor was too cold, the bottle was brought into warmer air, immersed in warm water, or more commonly held between the hands, till upon repeated trials with the thermometer the just temperature was found. It will be understood, that during the course of this heating or cooling, the bottle was very frequently shaken between each immersion of the thermometer; and the top of the neck was kept covered, either with the finger, or a silver cap made on purpose, as constantly as possible. Hot water was used to raise the temperature only in heats of



of  $30^{\circ}$  and upwards, inferior heats being obtained by applying the hands to the bottle: when the hot water was employed, the ball of the bottle was plunged into it, and again quickly lifted out, with the necessary shaking interposed, as often as was necessary for communicating the required heat to the liquor; but care was taken to wipe the bottle dry after each immersion, before it was shaken, lest any adhering moisture might by accident get into it. The liquor having by these means been brought to the desired temperature; the next operation was to fill up the bottle exactly to the mark upon the neck, which was done with some of the same liquor, by means of a glass funnel with a very small bore. Mr. Gilpin endeavoured to get that portion of the liquor which was employed for this purpose, pretty nearly to the temperature of the liquor contained in the bottle; but as the whole quantity to be added never exceeded ten grains, a difference of ten degrees in the heat of that small quantity, which is more than it ever amounted to, would have occasioned an error of only  $\frac{1}{30}$  of a degree in the temperature of the mass. Enough of the liquor was put in to fill the neck rather above the mark, and the superfluous quantity was then absorbed to great nicety, by bringing into contact with it the fine point of a small roll of blotting paper. As the surface of the liquor in the neck would be always concave, the bottom or centre of this concavity was the part made to coincide with the mark round the glass; and in viewing it care was taken, that the near and opposite sides of the mark should appear exactly in the same line, by which means all parallax was avoided. A silver cap, which fitted tight, was then put upon the neck, to prevent evaporation; and the whole apparatus was in that state laid in the scale of the balance, to be weighed with all the exactness possible.

The spirit employed by Mr. Gilpin was furnished to him by Dr. Dollfus, under whose inspection it had been rectified from rum supplied by government. Its specific gravity, at  $60^{\circ}$  degrees of heat, was ,82514. It was first weighed pure, in the abovementioned bottle, at every five degrees of heat, from  $30^{\circ}$  to  $100^{\circ}$  inclusively. Then mixtures were formed of it, and distilled water, in every proportion, from  $\frac{1}{4}$ th of the water to equal parts of water and spirit; the quantity of water added being successively augmented, in the proportion of five grains to one hundred of the spirit; and these mixtures were also weighed in the bottle, like the pure spirit, at every five degrees of heat. The numbers hence resulting are delivered in the following table; where the first column shews the degrees of heat; the second gives the weight of the pure spirit contained in the bottle at those different degrees; the third gives the weight of a mixture in the proportions of 100 parts by weight of that spirit to 5 of water, and so on successively till the water and the spirit are in equal parts. The bottle itself, with its cap, having been previously counterpoised, these numbers are the weights of the liquor contained in it, in grains and hundredths of a grain. They are the mean of three several experiments at least, as Mr. Gilpin always filled and weighed the bottle over again that number of times, if not oftener. The heat was taken at the even degree, as shewn by the thermometer, without any allowance in the first instance, because the coincidence of the mercury with a division, can be perceived more accurately than any fraction can be estimated; and the errors of the thermometers, if any, it was supposed would be less upon the grand divisions of 5 degrees, than in any others. It must be observed, that Mr. Gilpin used the same mixture throughout all the different temperatures, heating it up from  $30^{\circ}$  to  $100^{\circ}$ ; hence some small error in its strength may have been occasioned in the higher degrees, by more spirit evaporating than water; but

but this, it is believed, must have been trifling, and greater inconvenience would probably have resulted from interposing a fresh mixture.

Here follows in the report, a table of the weights in grains at the different degrees of temperature. These weights being elements from which specific gravities are computed, I have not thought it necessary to insert it here, more especially as the computation of the specific gravities appears to have been carefully revised and corrected by Mr. Gilpin, previous to the insertion of his large table in the Transactions for 1794.

In order to deduce the specific gravities from the numbers in the preceding table, it was necessary to weigh distilled water in the same vessel. This Mr. Gilpin did, in the same manner as before, at the different degrees of heat; and the result of his experiments is delivered in the following table, where the first column shews the heat, and the second gives the weight of the water, at that temperature, contained in the bottle.

*Weights and Specific Gravities of Distilled Water.*

Heat.	Weight of the Water.	Specific Gravity of the Water.	Specific Gravity as by the Table in Ph. Tr. 1794.
30°	Grains.		1,00074
35	2967,03	1,00087	1,00090
40	2967,34	1,00091	1,00094
45	2967,29	1,00084	1,00086
50	2966,97	1,00066	1,00068
55	2966,39	1,00040	1,00038
60	2965,39	1,00000	1,00000
65	2964,17	,99952	,99950
70	2962,72	,99896	,99894
75	2961,03	,99832	,99830
80	2959,13	,99762	,99759
85	2957,03	,99685	
90	2954,80	,99602	
95	2952,20	,99507	
100	2949,36	,99404	

The numbers in the additional column are taken from Mr. Gilpin's table in the Transactions for 1794, and are no doubt the most accurate.

There would be two methods for computing the specific gravity at the different temperatures from these numbers; one, by taking the weight of the water, at the particular temperature in question, for the standard; and the other by fixing on one certain temperature of the water, for instance 60°, to be the standard, with its bulk, at which that of the spirit at all different degrees shall be compared. Dr. Blagden preferred the latter method, though not the most usual, because it shews, more readily and simply, the progression observed in the changes of specific gravity, according to the heat and strength of the mixture. This method, however, rendered it necessary to make an allowance for the contraction and expansion of the bottle used for weighing the liquors, according to the deviation of their temperature from 60°, either below or above. To obtain this correction, the expansion of hollow glass was taken from General Roy's experiments in the lxxvth volume of the Philosophical Transactions,



as,0000517 of an inch upon a foot for every degree of heat; whence its effect, in enlarging the capacity of a sphere, was computed, and the resulting correction added to the weight of the liquors in heats below  $60^{\circ}$ , and subtracted from it in heats above. On the same account a third column is given, in the preceding table, to shew the specific gravity of water at the different temperatures, its weight at  $60^{\circ}$  being taken as the standard.

Another correction also became necessary, on account of the part of the stem of the thermometer which was not immersed in the liquor. This instrument, made by Ramsden, had its ball, .22 of an inch in diameter, and its stem 13 inches in length. From the ball to the commencement of the scale 3,6 inches of the stem were bare, and then the scale began, which reached from 15 to 110 degrees. The part of it particularly made use of in these experiments, namely from  $30^{\circ}$  to  $100^{\circ}$ , measured 6,82 inches. The scale was made of ivory, and carried divisions to every fifth of a degree, the quarters of which could be readily estimated; so that the instrument could be read off to twentieths of degrees. When the thermometer was immersed in the weighing bottle, the liquor reached up nearly to what would have been  $0^{\circ}$  upon its stem; hence, as the heat of the room in which the experiments were made remained about  $60^{\circ}$ , the correction for the different heat of the quicksilver in the stem from that in the ball of the thermometer was calculated according to Mr. Cavendish's table, given in the lxxvth volume of the Philosophical Transactions. Thus the real heat of the fluid in the weighing-bottle being found, an allowance was made to reduce it to the exact degree indicated on the scale of the thermometer.

The precise specific gravity of the pure spirit employed was ,82514; but to avoid an inconvenient fraction, it is taken, in constructing the table of specific gravities, as ,825 only, a proportional deduction being made from all the other numbers. Thus the following table gives the true specific gravity, at the different degrees of heat, of a pure rectified spirit, whose specific gravity at  $60^{\circ}$  is ,825, together with the specific gravities of different mixtures of it with water, at those different temperatures.

I have not copied the table from the report, excepting only the numbers answering to the temperatures 95 and 100. For I perceive that it differs in the two last decimal figures from the table published by Mr. Gilpin in the Transactions for 1794, to which reference has already been made. I suppose the two higher temperatures may have been omitted in that table as less useful, and perhaps less accurate. The following table is extracted from the last table of Mr. Gilpin. I should have willingly inserted the whole, in which the mixtures differ from each other by unity only, and are exhibited in measure as well as in weight, if the limits of the present work could have allowed it to be done. Mr. Gilpin's table likewise shews the bulk of the mixture, the diminution of bulk, the quantity of spirit per cent. and a decimal multiplier, which being applied to the bulk of the mixture, gives the measure of pure spirit in a mixture of that density.

Temperature	Specific Gravity of Pure Spirit	Specific Gravity of Mixture	Real
100	.82514	.82514	
95	.82514	.82514	
90	.82514	.82514	
85	.82514	.82514	
80	.82514	.82514	
75	.82514	.82514	
70	.82514	.82514	
65	.82514	.82514	
60	.82514	.82514	
55	.82514	.82514	
50	.82514	.82514	
45	.82514	.82514	
40	.82514	.82514	
35	.82514	.82514	
30	.82514	.82514	
25	.82514	.82514	
20	.82514	.82514	
15	.82514	.82514	
10	.82514	.82514	
5	.82514	.82514	
0	.82514	.82514	

*Real Specific Gravities at the different Temperatures.*

Heat.	The pure spirit.	100 grains of spirit to 5 grains of water.	100 grains of spirit to 10 grains of water.	100 grains of spirit to 15 grains of water.	100 grains of spirit to 20 grains of water.	100 grains of spirit to 25 grains of water.	100 grains of spirit to 30 grains of water.	100 grains of spirit to 35 grains of water.	100 grains of spirit to 40 grains of water.	100 grains of spirit to 45 grains of water.	100 grains of spirit to 50 grains of water.
30°	83896	84095	85957	86825	87585	88282	88921	89511	90054	90558	91023
35	83672	84769	85729	86587	87357	88059	88701	89294	89839	90345	90811
40	83445	84539	85507	86361	87134	87838	88481	89073	89617	90127	90596
45	83214	84310	85277	86131	86905	87613	88255	88849	89396	89909	90380
50	82977	84076	85042	85902	86676	87384	88030	88626	89174	89684	90160
55	82736	83834	84802	85664	86441	87150	87796	88393	88945	89458	89933
60	82500	83599	84568	85430	86208	86918	87569	88169	88720	89232	89707
65	82262	83362	84334	85193	85976	86686	87337	87938	88490	89006	89479
70	82023	83124	84092	84951	85736	86451	87105	87705	88254	88773	89252
75	81780	82878	83851	84710	85496	86212	86864	87466	88018	88538	89018
80	81530	82631	83603	84467	85248	85966	86622	87228	87776	88301	88781
85	81291	82396	83371	84243	85036	85757	86411	87021	87590	88120	88605
90	81044	82150	83126	84001	84797	85518	86172	86787	87360	87889	88376
95	80794	81900	82877	83753	84550	85272	85928	86542	87114	87654	88146
100	80548	81657	82639	83513	84308	85031	85688	86302	86879	87421	87915

Heat.	100 grains of spirit to 55 grains of water.	100 grains of spirit to 60 grains of water.	100 grains of spirit to 65 grains of water.	100 grains of spirit to 70 grains of water.	100 grains of spirit to 75 grains of water.	100 grains of spirit to 80 grains of water.	100 grains of spirit to 85 grains of water.	100 grains of spirit to 90 grains of water.	100 grains of spirit to 95 grains of water.	100 grains of spirit to 100 grains of water.
30°	91449	91847	92217	92563	92889	93191	93474	93741	93991	94222
35	91241	91640	92009	92355	92680	92986	93274	93541	93790	94023
40	91026	91428	91799	92151	92476	92783	93072	93341	93592	93827
45	90812	91211	91584	91937	92264	92570	92859	93131	93382	93621
50	90596	90997	91370	91723	92051	92358	92647	92919	93177	93419
55	90367	90768	91144	91502	91837	92145	92436	92707	92963	93208
60	90144	90549	90927	91287	91622	91933	92225	92499	92758	93002
65	89920	90328	90707	91066	91400	91715	92010	92283	92546	92794
70	89695	90104	90484	90847	91181	91493	91793	92069	92333	92580
75	89464	89872	90252	90617	90952	91270	91569	91849	92111	92364
80	89225	89639	90021	90385	90723	91046	91340	91622	91891	92142
85	89043	89460	89843	90209	90558	90882	91186	91465	91729	91969
90	88817	89230	89617	89988	90342	90668	90967	91248	91511	91751
95	88588	89003	89390	89763	90119	90443	90747	91029	91290	91531
100	88357	88769	89158	89536	89889	90215	90522	90805	91066	91310

Heat.	95 grains of spirit to 100 grains of water.	90 grains of spirit to 100 grains of water.	85 grains of spirit to 100 grains of water.	80 grains of spirit to 100 grains of water.	75 grains of spirit to 100 grains of water.	70 grains of spirit to 100 grains of water.	65 grains of spirit to 100 grains of water.	60 grains of spirit to 100 grains of water.	55 grains of spirit to 100 grains of water.	50 grains of spirit to 100 grains of water.
30°	94447	94675	94920	95173	95429	95681	95944	96209	96470	96719
35	94249	94484	94734	94988	95246	95502	95772	96041	96315	96579
40	94058	94295	94547	94802	95060	95328	95602	95879	96159	96434
45	93860	94096	94348	94605	94871	95143	95423	95705	95993	96280
50	93658	93897	94149	94414	94683	94958	95243	95534	95831	96126
55	93452	93696	93948	94213	94486	94767	95057	95357	95662	95966
60	93247	93493	93749	94018	94296	94579	94876	95181	95493	95804
65	93040	93285	93546	93822	94099	94388	94689	95000	95318	95635
70	92828	93076	93337	93616	93898	94193	94500	94813	95139	95469
75	92613	92865	93132	93413	93695	93989	94301	94623	94957	95292
80	92393	92646	92917	93201	93488	93785	94102	94431	94768	95111



Heat.	45 grains of spirit to 100 grains of water.	40 grains of spirit to 100 grains of water.	35 grains of spirit to 100 grains of water.	30 grains of spirit to 100 grains of water.	25 grains of spirit to 100 grains of water.	20 grains of spirit to 100 grains of water.	15 grains of spirit to 100 grains of water.	10 grains of spirit to 100 grains of water.	5 grains of spirit to 100 grains of water.
30°	96967	97200	97418	97635	97860	98108	98412	98804	99334
35	96840	97086	97319	97556	97801	98076	98397	98804	99344
40	96706	96967	97220	97472	97737	98033	98373	98795	99345
45	96563	96840	97110	97384	97666	97980	98338	98774	99338
50	96420	96708	96995	97284	97589	97920	98293	98745	99316
55	96272	96575	96877	97181	97500	97847	98239	98702	99284
60	96122	96437	96752	97074	97410	97771	98176	98654	99244
65	95962	96288	96620	96959	97309	97688	98106	98594	99194
70	95802	96143	96484	96836	97203	97596	98028	98527	99134
75	95638	95987	96344	96708	97086	97495	97943	98454	99066
80	95467	95826	96192	96568	96963	97385	97845	98367	98991

From this table, when the specific gravity of any spirituous liquor is ascertained, it will be easy to find the quantity of rectified spirit of the abovementioned standard, contained in any given quantity of it, either by weight or measure. As common arithmetic is competent to furnish the rules for this purpose, it would be superfluous to give them here. Dr. Blagden is of opinion, that all the objects of enquiry should be reduced to tables; the first of which might exhibit the specific gravities of different mixtures, from 1 to 100 parts of water, increasing by one, at every degree of heat from 40 to 80, being the utmost limits of temperature that can be wanted in common practice. This table need only be calculated to three places of figures, which will always give the quantity of spirit true within a fiftieth part of the whole, and in the most usual degrees of heat within a hundredth; and to this number of figures the aerometer, or hydrometer, shewing the specific gravities, could be suited. A further reason for continuing only to three places of figures is, that, accurate as Mr. Gilpin's experiments have been, some irregularities are found in the two last of the five decimals to which his tables are calculated. The greatest of these irregularities, Dr. Blagden is of opinion, do not exceed the quantity corresponding to a difference of one-fifth of a degree of heat, and in general they are much less. A table might be constructed to shew what the numbers would probably have been to the five places of decimals, if there had been no kind of error in the experiments. Another table should be of the volumes, exhibiting what proportion the spirit and water bore to each other by measure or bulk, in the different mixtures; whence might be calculated a very useful table of diminutions, to shew when a given weight, or volume, of a certain spirit and water are mixed together, how much their bulk would be diminished; or what is called by distillers the concentration. From such a table the distiller could learn what quantity of water he must mix with spirit of a given strength, in order to reduce it to proof spirit, or any other strength; and likewise what quantity of proof spirit, or spirit of any other strength, he may obtain, by adding water to spirit of a given strength; both circumstances very necessary to be known in the trade, and which some of the sliding rulers now in use profess to point out.

Dr. Blagden chose this point of the thermometer 60° in preference to 55°, because it is much the most suitable for experiments, being the temperature at which a room feels pleasant, and in which any operation, however slow and tedious, can be executed without the uneasy sensation of cold; for this reason it has been adopted by many English philosophers. In the table formerly recommended,

mended, from 40 to 80 degrees of the thermometer, it will be the middle temperature.

The specific gravity of ,825 having been fixed upon as the standard of rectified spirit in the tables, Mr. Gilpin was desired to ascertain by experiment what proportion of water would be necessary to reduce the lightest alcohol in his possession to that standard. This was some alcohol already mentioned, which Mr. Lewis had furnished; and its specific gravity being ,814196 at 60°, 3000 grains of it mixed with 135 grains of distilled water formed a compound, whose specific gravity was ,825153; that is in round numbers, 100 grains of alcohol at ,814 with 4,5 grains of water form the standard of spirit at ,825.

Dr. Blagden observes, that the small quantities mixed and weighed ought not to be any objection to the preceding experiments; that if the instruments be exceedingly exact, and the experimenters equal to the task of using them properly, the errors upon moderate quantities will be quite as small in proportion as upon large; and that in this particular instance, where the greatest source of error lay in the determination of the heat, the smaller quantities had in that respect an evident advantage, it being much easier to bring six ounces of a liquor to an uniform temperature, than so many gallons. One of the most essential instruments, namely the balance, was so much superior in nicety to any thing that could be wanted in these experiments, that error in weighing must be thrown entirely out of the question. It was constructed by Mr. Ramsden; and some account, though very imperfect, of its admirable mechanism, as well as of its extreme sensibility, even when loaded with considerable weights, has been given in the xxxiiiid volume of the *Journal de Physique*.

Dr. Blagden concludes this part of the report with observing, that as the experiments were made with pure spirit and water, if any extraneous substances are contained in the liquor to be tried, the specific gravity in the tables will not give exactly the proportions of water and spirit in it. The substances likely to be found in spirituous liquors, where no fraud is suspected, are essential oils; sometimes empyreumatic, mucilaginous or extractive matter, and perhaps some saccharine matter. The effect of these, in the course of trade, seems to be hardly such as would be worth the cognizance of the excise, nor could it easily be reduced to certain rules. Essential and empyreumatic oils are nearly of the same specific gravity as spirit, in general rather lighter, and therefore, notwithstanding the mutual penetration, will probably make little change in the specific gravity of any spirituous liquor in which they are dissolved. The other substances are all heavier than spirit; the specific gravity of common gum being 1,482, and of sugar 1,606, according to the tables of M. Brisson. The effect of them therefore will be to make spirituous liquors appear less strong than they really are. An idea was once entertained of endeavouring to determine this matter with some precision; and accordingly Dr. Dollfus evaporated 1000 grains of brandy, and the same quantity of rum, to dryness; the former left a residuum of 40 grains, the latter only of 8½ grains. The 40 grains of residuum from the brandy, dissolved again in a mixture of 100 of spirit, with 50 of water, increased its specific gravity ,00041: hence the effect of this extraneous matter upon the specific gravity of the brandy containing it, would be to increase the fifth decimal by 6 nearly, equal to what would indicate in the above-mentioned mixture, about one-seventh of a grain of water more than the truth, to 100 of spirit; a quantity much too minute for the consideration of government\*.

\* Here ends the Report of Dr. Blagden.

The



The most remarkable characteristic property of ardent spirit, is its solubility or combination in all proportions with water; a property possessed by no other combustible substance. When it is burned in a chimney which communicates with the worm-pipe of a distilling apparatus, the product which is condensed is found to consist of water, which exceeds the spirit in weight about one eighth part. If ardent spirit be burned in closed vessels with vital air, the product is found to be water and fixed air. Whence it is inferred that ardent spirit consists of inflammable air, united either to fixed air or its acidifiable base; and that the vital air, uniting on the one part with the inflammable air, forms water; and on the other with the base of the fixed air, forms that acid\*.

A considerable number of the uses of this fluid as a menstruum have passed under our observation in the various articles of this work. The mutual action between ardent spirit and acids produces a light, volatile, and inflammable oil, called ether. See ETHER. Pure alkalis unite with spirit of wine, and form alkaline tinctures. Few of the neutral salts unite with this fluid, except such as contain the volatile alkali. The mild fixed alkalis, or combinations of alkali and fixed air, are not soluble in it. From the strong attraction which exists between ardent spirit and water, it unites with this last in saline solutions, and in most cases precipitates the salt. This is a pleasing experiment, which never fails to surprise those who are unacquainted with chemical effects. If, for example, a saturated solution of nitre in water be taken, and an equal quantity of strong spirit of wine be poured upon it, the mixture will constitute a weaker spirit, which is incapable of holding the nitre in solution; it therefore falls to the bottom instantly, in the form of minute crystals.

The degrees of solubility of many neutral salts in spirit of wine, are exactly ascertained by experiments made by Macquer, of which an account is published in the Memoirs of the Turin Academy. The spirit of wine he employed was carefully freed from superabundant phlegm by repeated rectifications, without addition of any intermediate substance. A phial which contained one Paris ounce of distilled water when Reaumur's thermometer was at six degrees above the freezing point, contained of this rectified spirit six gros and fifty-four grains. The salts employed in his experiments were previously deprived of their water of crystallization by a careful drying. He poured into a matras, upon each of the salts thus prepared, half an ounce of his spirit of wine, and set the matras in a sand-bath. When the spirit began to boil, he filtrated it while it was hot, and left it to cool that he might observe the crystallizations which took place. He then evaporated the spirit, and weighed the saline residuums. He repeated these experiments a second time, with this difference, that instead of evaporating the spirit in which the salt had been digested, he set fire to it in order to examine the phenomena which its flame might exhibit. The principal results of his experiments are subjoined.

\* For an account of these experiments, and the precautions necessary to be attended to in making them, consult the Memoirs of M. Lavoisier, in the Memoirs of the Royal Academy at Paris for 1781 and 1784.

Quantity of grains.	Salts soluble in 200 grains of spirit.	Peculiar phenomena of the flame.
0	Vitriolated tartar	None
4	Nitre	{ Flame larger, higher, more ardent, yellow, and luminous
5	Salt of Sylvius	{ Large, ardent, yellow, and luminous
0	Glauber's salt	Considerably red
15	Cubic nitre	Yellow, luminous, detonating
0	Common salt	Larger, more ardent, and reddish
0	Vitriolic ammoniac	None
108	Nitrous ammoniac	Whiter, more luminous
24	Sal ammoniac	None
0	Selenites	None
288	Nitre with calcareous basis	{ Larger, more luminous, red and decrepitating
288	{ Marine salt with calcareous basis	{ Like that of the calcareous nitre
0	Vitriol of silver	None
84	Nitre of silver	None
0	Luna cornea	None
0	Vitriol of mercury	None
0	Nitre of mercury	None
204	Corrosive sublimate	{ Large, yellow, luminous and decrepitating
0	Martial vitriol	None
4	Martial nitre	Red and decrepitating
36	Martial marine salt	{ More white, luminous and sparkling
0	Vitriol of copper	None
48	Cupreous nitre	{ More white, luminous, and green, much smoke. The saline residuum became black and burnt
48	Cupreous marine salt	{ Fine green, white, and red flogurations.

Macquer accompanies the relation of his experiments with many judicious reflections, not easily capable of abridgment.

Sulphur does not appear to be acted upon more strongly by ardent spirit than by water. If sulphur in sublimation meet with the vapour of spirit of wine, a very small portion combines with it, which communicates an hepatic odour to the fluid. The increased surface of the two substances appears to favour the combination.

Phosphorus is sparingly soluble in ardent spirit, but in greater quantity by heat than in cold. The addition of water to this solution affords an opaque milky fluid, which gradually becomes clear by the subsidence of the phosphorus.

\* These four grains were an acid matter. This salt could not be dried without decomposition.



Earths seem to have scarce any action upon ardent spirit. Quick-lime, however, produces some alteration in this fluid, by changing its flavour and rendering it of a yellow colour. A small portion is probably taken up.

Soaps are dissolved with great facility in ardent spirit, with which they combine more readily than with water. None of the metals, nor their calces, are acted upon by this fluid. Resins, essential oils, camphor, bitumen, and various other substances, are dissolved with great facility in ardent spirit, from which they may be precipitated by the addition of water.

According to the experiments and deductions of Lavoisier and other modern chemists, the vinous fermentation by which ardent spirit is produced is an operation of considerable simplicity. This author, in his Elements of Chemistry, has even ventured to tabulate the whole of the results; which, if repeated and sufficiently varied, would no doubt greatly advance our knowledge in this department of science. I shall conclude the present article with his very perspicuous explanation of this process, retaining in justice to him the terms of the modern nomenclature, which are here but few, and are explained under our article NOMENCLATURE.

The manner in which wine, cyder, mead, and all the liquors formed by the spirituous fermentation, are produced, is well known to every one. The juice of grapes or of apples being expressed, and the latter being diluted with water, they are put into large vats, which are kept in a temperature of at least  $54.5^{\circ}$  of the thermometer. A rapid intestine motion or fermentation very soon takes place, numerous globules form in the liquid and burst at the surface; when the fermentation is at its height, the quantity of gas disengaged is so great as to make the liquor appear as if boiling violently over a fire. When this gas is carefully gathered, it is found to be carbonic acid, or fixed air free from admixture with any other species of air or gas, but usually containing a portion of ardent spirit.

When the fermentation is completed, the juice of grapes is changed, from being sweet and full of sugar, into a vinous liquor, which no longer contains any sugar, and from which we procure by distillation an inflammable liquor, known in commerce under the name of spirit of wine.

This operation is one of the most extraordinary in chemistry. We must examine whence proceed the disengaged carbonic acid and the inflammable liquor produced, and in what manner a sweet vegetable oxyd becomes thus converted into two such opposite substances, whereof one is combustible and the other eminently the contrary. To solve these two questions it is necessary to be previously acquainted with the analysis of the fermentable substance, and of the products of the fermentation.

We may lay it down as an incontestable axiom, that in all the operations of art and nature, nothing is created; an equal quantity of matter exists both before and after the experiment; the quality and quantity of the elements remain precisely the same; and nothing takes place beyond changes and modifications in the combinations of these elements. Upon this principle the whole art of performing chemical experiments depends: we must always suppose an exact equality between the elements of the body examined, and those of the products of its analysis.

Hence, since from must of grapes we procure alcohol and carbonic acid, Lavoisier concludes he has undoubted right to suppose that must consists of carbonic acid and of alcohol: but his translator justly remarks, that in this assertion the consequences

consequences do not strictly follow from the premises; because from the must of grapes we procure carbonic acid and alcohol; it is a necessary consequence that the original must contains the constituent elements of carbonic acid and alcohol, but not that these products of fermentation are already formed. From these premises we have two methods of ascertaining what passes during vinous fermentation: either by determining the nature of, and the elements which compose, the fermentable substances, or by accurately examining the products resulting from fermentation; and it is evident that the knowledge of either of these must lead to accurate conclusions concerning the nature and composition of the other. From these considerations it became necessary, accurately to determine the constituent elements of the fermentable substances; and for this purpose he did not make use of the compound juices of fruits, the rigorous analysis of which is perhaps impossible, but made choice of sugar, which is easily analysed. This substance he states to be true vegetable oxyd with two bases, composed of hydrogen and carbon, brought to the state of an oxyd by means of a certain proportion of oxygen; and these three elements are combined in such a way, that a very slight force is sufficient to destroy the equilibrium of their connection. By a long train of experiments, made in various ways, and often repeated, he ascertained that the proportions in which these ingredients exist in sugar are, nearly eight parts of hydrogen, sixty-four parts of oxygen, and twenty-eight parts of carbon, all by weight, forming one hundred parts of sugar.

Sugar must be mixed with about four times its weight of water, to render it susceptible of fermentation; and even then the equilibrium of its elements would remain undisturbed, without the assistance of some substance to give a commencement to the fermentation. Lavoisier's translator, however, remarks here, that this is not strictly true; for, especially in warm weather, all syrups are apt to run into fermentation, unless very rich of the sugar, and carefully preserved. At the same time this spontaneous fermentation is not so regular as when assisted by yeast, and is apt to become in part acetous before completing the vinous process.

The commencement of the fermentation is accomplished by means of a little yeast from beer; and when the fermentation is once excited, it continues of itself until completed. Lavoisier usually employed ten pounds of yeast, in the state of paste, for each hundred pounds of sugar, with as much water as is four times the weight of the sugar. The following is the result of his experiments, exactly as they were obtained, preserving even the fractions produced by calculation.

TABLE I. *Materials of Fermentation.*

		lbs.
Water	—	400
Sugar	—	100
Yeast in paste, 10 lbs. } composed of	Water	7,239.1493
	Dry yeast	2,760.8507
Total		510 lbs.



TABLE II. *Constituent Elements of the Materials of Fermentation.*

407.2391493 lbs. of water,	{ Hydrogen —	61.0858724	
composed of	{ Oxygen —	346.1532769	
	{ Hydrogen —	8	
100 lbs. of sugar, composed of	{ Oxygen —	64	
	{ Carbon —	28	
	{ Hydrogen —	.2900716	
2.7608507 lbs. of dry yeast,	{ Oxygen —	1.6437457	
composed of	{ Carbon —	.7876519	
	{ Azot —	.0393815	
Total weight		510 lbs.	

TABLE III. *Recapitulation of these Elements.*

		lbs.	
of the water	—	340	
of the water in the yeast	—	6.1532769	lbs.
Oxygen	{ of the sugar —	64	411.7970226
	{ of the dry yeast —	1.6437457	
	{ of the water —	60	
Hydrogen	{ of the water in the yeast —	1.0858724	69.3759440
	{ of the sugar —	8	
	{ of the dry yeast —	.2900716	
Carbon	{ of the sugar —	.28	28.7876519
	{ of the yeast —	.07876519	
Azot of the yeast	—	—	.0393815
In all		510 lbs.	

Having thus accurately determined the nature and quantity of the constituent elements of the materials submitted to fermentation, we have next to examine the products resulting from that process. For this purpose Lavoisier placed the above 510 lbs. of fermentable liquor in a proper apparatus, by means of which he could accurately determine the quantity and quality of gas disengaged during the fermentation, and could even weigh every one of the products separately, at any period of the process he judged proper.

An hour or two after the substances are mixed together, especially if they are kept in a temperature of from 66° to 73° of the thermometer, the first marks of fermentation commence: the liquor turns thick and frothy; little globules of air are disengaged, which rise and burst at the surface; the quantity of these globules quickly increases, and there is a rapid and abundant production of very pure carbonic acid, accompanied with a scum, which is the yeast separating from the mixture. After some days, less or more according to the degree of heat, the intestine motion and disengagement of gas diminish; but these do not cease entirely, nor is the fermentation completed for a considerable time. During the process, 35.3458116 lbs. of dry carbonic acid are disengaged, which carry along with them 13.9140625 lbs. of water. There remains in the vessel 460.7401259 lbs. of vinous liquor, slightly acidulous. This is at first muddy, but clears of itself, and deposits a portion of yeast. When we separately analyse

all these substances, which is effected by very troublesome processes, we have the results as given in the following tables:

TABLE IV. *Products of Fermentation.*

35.3458116 lbs. of carbonic acid, composed of	Oxygen	—	—	25.4490017
	Carbon	—	—	9.8968099
408.9780816 lbs. of water, composed of	Oxygen	—	—	347.6314019
	Hydrogen	—	—	61.3466797
57.7016059 lbs. of dry alcohol, composed of	Oxygen, combined with hydrogen	—	—	31.3897570
	Hydrogen, combined with oxygen	—	—	5.5393880
	Hydrogen, combined with carbon	—	—	4.0390625
	Carbon, combined with hydrogen	—	—	16.7333984
2.5000000 lbs. of dry acetic acid, composed of	Hydrogen	—	—	0.1562500
	Oxygen	—	—	1.7187500
	Carbon	—	—	0.6250000
4.0940755 lbs. of residuum of sugar, composed of	Hydrogen	—	—	0.3275825
	Oxygen	—	—	2.6201172
	Carbon	—	—	1.1463758
1.3804254 lbs. of dry yeast, composed of	Hydrogen	—	—	0.1450738
	Oxygen	—	—	0.8218317
	Carbon	—	—	0.3938802
	Azot	—	—	0.0196397
510 lbs.				510 lbs.

TABLE V. *Recapitulation of the Products.*

409.6308595 lbs. of oxygen contained in the	Water	—	—	347.6314019
	Carbonic acid	—	—	25.4490017
	Alcohol	—	—	31.3897570
	Acetic acid	—	—	1.7187500
	Residuum of sugar	—	—	2.6201172
	Yeast	—	—	0.8218317
28.7954643 lbs. of carbon contained in the	Carbonic acid	—	—	9.8968099
	Alcohol	—	—	16.7333984
	Acetic acid	—	—	0.6250000
	Residuum of sugar	—	—	1.1463758
	Yeast	—	—	0.3938802
71.5540365 lbs. of hydrogen contained in the	Water	—	—	61.3466797
	Water of the alcohol	—	—	5.5393880
	Combined with the carbon of the alcohol	—	—	4.0390625
	Acetic acid	—	—	0.1562500
	Residuum of sugar	—	—	0.3275825
	Yeast	—	—	0.1450738
0.0196397 lbs. of azot in the yeast		—	—	0.0196397
510 lbs.				510 lbs.



In the calculation of these results, Lavoisier has been exact even to minuteness; not that it is possible in experiments of this nature, actually to carry our accuracy so far; but as the experiments were made only with a few pounds of sugar, and as, for the sake of comparison, he reduced the results of the real experiments to the quintal, or imaginary hundred pounds, he thought it necessary to leave the fractional parts precisely as produced by calculation.

When we consider the results presented by these tables with attention, it seems easy to ascertain what occurs during fermentation. In the first place, out of the 100lbs. of sugar employed, 4.0940755lbs. remain, without having suffered decomposition: so that in reality we have only operated upon 95.9059245lbs. of sugar; that is to say, upon 61.37979168lbs. of oxygen, 7.67247396lbs. of hydrogen, and 26.85365886lbs. of carbon. By comparing these quantities, we find that they are fully sufficient for forming the whole of the alcohol, carbonic acid, and acetous acid, produced by the fermentation. It is not, therefore, necessary to suppose that any water has been decomposed during the experiment, unless it be pretended that the oxygen and hydrogen exist in the sugar already combined in that form:—On the contrary, it has already been made evident that hydrogen, oxygen, and carbon, the three constituent elements of vegetable substances, remain in a state of equilibrium, or mutual union with each other, which subsists so long as this union remains undisturbed by increased temperature, or by means of some new compound attraction; and that then only these elements combine, two and two together, to form water and carbonic acid.

The effects of the vinous fermentation upon sugar are thus reduced to the mere separation of its elements into two portions: one part is oxygenated at the expence of the other, so as to form carbonic acid, while the other part, being disoxygenated in favour of the former, is converted into the combustible substance called alcohol; therefore, if it were possible to re-unite alcohol and carbonic acid together, we ought to form sugar. It is evident, that the carbon and hydrogen in the alcohol do not exist in the state of oil, but that they are combined with a portion of oxygen, which renders them miscible with water; wherefore these three substances, oxygen, hydrogen, and carbon, exist here likewise in a species of equilibrium or reciprocal combination; and in fact, when they are made to pass through a red hot tube of glass, or porcelain, this union or equilibrium is destroyed; these elements become re-combined two and two, and water and carbonic acid are formed.

Lavoisier, in his first Memoirs on the formation of water, had advanced that it was decomposed in a great number of chemical experiments, and particularly during the vinous fermentation. He then supposed that water existed ready formed in sugar; but subsequent experiments convinced him that sugar only contains the elements proper for composing it.

He concludes his remarks upon vinous fermentation by observing, that it furnishes us with the means of analysing sugar, and every vegetable fermentable matter. We may consider the substances submitted to fermentation, and the products resulting from that operation, as forming an algebraic equation; and, by successively supposing each of the elements in this equation unknown, we can calculate their values in succession, and thus verify our experiments by calculation, and our calculations by experiments, reciprocally. He adds, that he has often successfully employed this method for correcting the first results of his experiments,

periments, and directing him in the proper road for repeating them to advantage.

**SPIRIT OF LIBAVIUS.** The same thing as the smoking liquor of Libavius; for which see the article **TIN**.

**SPIRIT OF NITRE.** See **NITROUS ACID**. In the shops the pure nitrous acid is called spirit of nitre, and the less pure used by artificers, is called aqua fortis. Some authors assert that the common aqua fortis being distilled from impure nitre, and containing marine acid, has in many cases the effect of an aqua regia. We have already remarked that the refiners purify their aqua fortis by adding a small portion of the nitrous solution of silver, the metallic part of which combining with the marine acid falls down in the form of luna cornea.

**SPIRIT OF SALT.** See **MARINE ACID**.

**SPIRIT OF SULPHUR.** The volatile vitriolic acid. See **ACID VITRIOLIC**, also **SULPHUR**.

**SPIRIT OF VENUS.** The acerous acid distilled from the crystals of verdigrise without addition. It appears to be in the aerated state, and accordingly is much more active than ordinary acerous acid. It is totally inflammable.

**SPIRIT OF VINEGAR.** The common acerous acid, or distilled vinegar.

**SPIRIT OF VITRIOL.** This name has been given to the first portions of acid which come over in a diluted state, when vitriolic acid is distilled or concentrated. It has also been applied to every other weak vitriolic acid.

**SPIRIT VOLATILE OF SAL AMMONIAC.** The volatile alkali which comes over in a caustic state combined with water in the distillation of sal ammoniac with slaked-lime, was originally called by this name. See **ALKALI VOLATILE**.

**SPIRIT OF WINE.** See **SPIRIT ARDENT**.

**SPIRITUS RECTOR.** Boerhaave and other chemists give this name to a very attenuated subtle principle, in which the smell of odorant bodies peculiarly resides.

To obtain the spiritus rector from odoriferous substances, these matters are to be distilled in the cucurbit or body of an alembic placed in a water bath, with a very gentle heat, that is from one hundred to one hundred and ten degrees of heat, till we perceive what rises in distillation has little or no smell.

The principle of smell in bodies is in general too subtle and too fugacious to be obtained alone and pure by any method whatever. Accordingly, it rises by means of the water contained in substances distilled in order to procure it, and is dispersed and overwhelmed in water. If the odoriferous matters from which the spiritus rector is required to be procured were absolutely dry, and contained no other volatile principles, a little water or spirit of wine ought necessarily to be added, to furnish a kind of basis to this spirit, which would otherwise be dissipated and evaporated, so that it could not be collected.

This principle of the smell of bodies is miscible with water, with spirit of wine, and with oils. It seems however to be of different natures, according to the substances which furnish it. Its properties shew that it is in general composed of an inflammable principle, and of a saline substance, both extremely attenuated. But the spiritus rector of some substances appears to be more of a saline, and that of others more of an oily nature.

All matters, the smell of which is quick, pungent, and which do not affect the brain and nervous system, as the acrid, cruciform plants, and substances which



which undergo the acid fermentation, contain a spiritus rector, probably more saline than oil.

Those on the contrary whose smell is sweet, nauseous or strong, without acrimony or pungency, and which affect the head by curing or occasioning hysterical or convulsive accidents; such as ambergrise, musk, castor, burnt coffee, opium, narcotic plants, camphor, all aromatic plants, and lastly, the substances which undergo the spirituous fermentation; have, according to all appearance, a spiritus rector which partakes of the nature of oil. For, besides that the effects produced by these substances are similar to those of the vapour of charcoal, the spiritus rector of some of them is really inflammable; as for instance, that of fraxinella, the exhalations from which form an atmosphere that may be inflamed with a lighted taper.

The spiritus rector of all aromatic plants seems particularly to be associated with their essential oils; at least all these oils contain a good deal of it. To this principle they certainly owe their smell, and probably their volatility and thinness; for those which from age, or from not having been preserved in well closed vessels, have lost their proper smell, are at the same time much less thin and volatile, since they are no longer capable of being raised by the heat of boiling water; and besides, the plants from which the spiritus rector has been obtained, furnish little or no essential oil. See Oils (Essential).

The spiritus rector, even that of aromatic plants, although it be of an oily nature, is perfectly miscible with water; which can only proceed from its great tenuity, or from the saline principle which enters its composition.

**SPONGE.** A soft, light, very porous, and compressible substance, readily imbibing water, and distending thereby. It is found adhering to rocks, particularly in the Mediterranean sea, about the islands of the Archipelago. It is generally supposed to be a vegetable production: nevertheless some observations, made by Jussieu, give room to suspect that it is of animal origin. Chemical experiments favour this supposition: analysed it yields the same principles with animal substances in general. Lewis says, that the volatile salt is in larger quantity than he obtained from any animal matter, except the bags of the silk-worm. On this salt seem to depend the virtues of the officinal *Spongia usta*. Crude sponge, from its property of imbibing and distending by moisture, is sometimes made use of as a tent for dilating wounds and ulcers.

It adheres strongly to the mouths of wounded vessels; and when retained by proper compression, it has prevented considerable bleedings preferably to agarie, puff-ball, &c. On account of the saline matter contained in burnt sponge, it has been used in scrophulous and other cutaneous affections, and in bronchocèle.

**SPUMA-MARIS.** See KEFFEKIL.

**STAINING OF WOOD.** The practice of staining chiefly takes place in solid and inflexible bodies; and as it is performed with different views, it is also different in its nature. Here this kind only will be considered, in which a body is dyed on its surface, or the colour which it has already is changed. It has commonly this peculiarity, that the penetrating materials are only laid on the bodies with a brush; though the latter may also sometimes be boiled or steeped in the former without receiving any detriment. It is used for wood, leather, horn, ivory, and various kinds of stones. In all these cases attention ought to be paid to the natural composition of the bodies and their properties, as well as to the nature of the staining materials.

For the staining of wood, sharp corrosive fluids must be used, such as spirit of

of vitriol, aqua fortis, or a solution of blue or of green vitriol, according to the nature of the wood, or to the state into which it has been put by means of art. Otherwise wood may be stained red, by previously soaking it in alum water, and then putting it into a decoction of brazil wood, in lime-water. It may be made blue with a somewhat diluted solution of indigo in vitriolic acid. It assumes a green colour in a decoction of verdigrise, sal ammoniac and vinegar; black in a decoction of galls, logwood, vitriol, filings of iron, and vinegar. For leather, on the contrary, these sharp corrosive substances must be avoided; because its durability will be destroyed by them. To give it a red colour, the skins, after being properly prepared, are dipped into a solution of tartar and common salt, then put into a bath of madder, tartar, alum, and calcined oyster-shells, and sometimes also at last into a simple decoction of brazil wood. Or the skins are steeped in alum water, and afterwards stained with a decoction of gum lac, brazil wood, alum and sal ammoniac. They acquire a blue colour by being rubbed over with a solution of indigo and alum-water. They become yellow in a decoction of turmeric in lime-water; and green with sap green dissolved in lime-water. The above-mentioned baths may in like manner be used for horn and ivory; besides which the diluted solutions of mercury, iron, copper, and silver may also be employed. These latter liquors may likewise be laid upon all kinds of trinkets and toys made of agate. For the staining of marble, coloured resinous solutions in spirit of wine, or in ethereal oils, must be used; and, to promote the penetration of them into its substance, a little heat must be had recourse to. In the same manner, alabaster also may be stained with various colours, in particular red, with a decoction of brazil-wood and alum; blue with elder-berries and alum; yellow with saffron or turmeric, and other liquid colours of this kind. It is in a similar kind of staining that the effects of common writing-ink consist. See *INK*.

**STALACTITES.** These are found suspended from vaults, being formed by the oozing of water charged with calcareous particles, and gradually evaporating, leaving those particles behind: this deposition can scarce be called a crystallization, as the earthy particles scarcely appear to have been dissolved, nor even very minutely divided, though this sometimes happens; whereas transparent spars appear to have been formed from a solution in water, by means of the aerial acid. Stalactites are of a lamellar or granular texture, and either in a branchy form, or in that of perforated cones, or globular, and then called stalagmites, oolites, pisolites, &c. Most of these stones contain a slight mixture of clay and calx of iron. And hence, they are of a gray, brown, yellow, or blackish colour.

**STEATITES.** A stone of the magnesian kind, consisting, according to Kirwan, of 80 parts flint, 17 magnesia, 2 clay, and 1 iron. It is always of a green or greenish colour, and so soft as to be scraped by the nail; of a soft soapy feel; its specific gravity is from 2.433 to 2.78. It is not easily diffusible in water, nor rendered ductile by mixture with it.

It does not effervesce with acids, and is very slowly and only partially soluble in the three mineral acids.

In fire it hardens, but is infusible per se, and becomes whiter. It is imperfectly melted by mineral alkali and microcosmic salt, but more perfectly by borax. It is apt to corrode the crucibles.

**STEEL.** Under the articles *IRON* and *ORES OF IRON*, much may be seen concerning the properties and applications of this useful metal, and its conversion.



tion into steel. In the present article, I shall avail myself of the valuable collection of facts brought together in the *Encyclopedie Methodique*; not scrupling however, to make whatever abridgment or alteration may appear necessary.

The distinctive character of steel is, that when ignited and immediately plunged into cold water, it becomes much harder than it was before. Several of the methods of effecting this conversion have already been as amply described under the article *IRON*, as our limits would admit. Mr. Morveau discusses the five following questions. 1. Is every kind of iron capable of being converted into steel? 2. By what means is this conversion to be effected? 3. What are the processes for reducing it back to the state of iron? 4. What are the effects of hardening, tempering, and annealing steel? 5. What are the characters and properties which distinguish steel from iron?

It is certain that every kind of iron is convertible into steel. This is mere matter of fact. But from the imperfection of the experiments yet made upon this metal, numerous though they are, it must be confessed that the various differences of quality in steel, which are extreme, arise much more from original differences in the iron made use of, than from any management in the manufacturing processes; and that these original differences have been very little investigated, but exist more probably in the ore itself, than in the fuels, fluxes, or manipulations at the iron founderies and refineries. Bergman, in his treatise on the white ores of iron, has positively ascribed the excellence of the white steel ore to a proportion of manganese which it contains. (\* See Section X. of his Treatise, p. 230 Eng. Trans.) But we know of no direct experiments tending to ascertain the advantages which might arise from an attempt to combine manganese with iron; which would indeed require some address in the chemist, on account of the extreme temperature requisite for the fusion of either metallic substance. Morveau is of opinion, that the manganese of the sparry iron ores becomes vitrified, and assists in the more perfect fusion and depuration of the iron, and in no other way; and he is more confirmed in this opinion, by observing not only that good steel is procurable from ores of other kinds, but that Bergman himself examined several steels which did not afford more than one two-hundredth part of their weight of manganese; a proportion which he thinks can hardly affect the nature of the steel, when ductile irons are capable of being combined with near one-third of their weight, without losing their ductility.

Upon this argument I must remark, that the real conversion of iron into steel, by cementation, is effected by an addition of weight so small, that inaccurate observers have been disposed to assert that the gain is altogether insensible.

The English steel made by cementation, and afterwards fused, and sold under the name of cast-steel, in bars, plates, and other forms, possesses great reputation for its uniformity of texture, and other good qualities. I have been informed by various authorities, of which the respectability and connections are calculated to produce the most absolute confidence, that all the prime steels of England are made from Swedish iron, known in this country by the name of steel-iron, of three different marks, the first of which indicates the best quality, and the third the worst; and that the whole produce of this kind of iron is monopolized under a contract with Sweden, by two commercial houses, one in London, and the other at Birmingham, the names of which were mentioned to me. Hence it seems probable that the useful art of steel-making might be  
I much

much promoted by examining this material, and ascertaining chemically, as well as mechanically, what may be the cause of its superiority. By chemical examination, I mean the determination of its component parts, and by mechanical examination, whether those parts are uniformly distributed through the whole mass. For one of the greatest imperfections of steel consists in this unequal distribution, which produces a correspondent inequality of hardness in the several parts of such utensils as may be made of it.

The conversion of iron into steel, either by fusion, viz. the direct change of crude iron into steel, or by cementation of bar-iron, present many objects of interesting enquiry. From various experiments of Bergman it appeared, that good crude iron, kept for a certain time in a state of fusion, with such additions as appeared calculated to produce little other effect than that of defending the metal from calcination, became converted into steel with loss of weight. These facts are conformable to the general theory of Vandermonde, Monge and Berthollet, which is chiefly insisted on under the article IRON. For, according to their researches, it should follow, that part of the plumbago of the crude iron was dissipated, and the remainder proved to be such in proportion as constitutes steel. The same chemist cemented crude iron with plumbago, and found that the regulus had lost no weight. Morveau repeated the experiment with gray crude iron. The loss of weight was little, if any. The regulus exhibited the black spot by the application of nitrous acid, as steel usually does, but it did not harden by ignition and plunging in water. Hence, I conclude that it was scarcely altered. For crude irons also exhibit the black spot, and cannot by common management acquire the hardness of steel.

From the experiments of the three excellent chemists last mentioned, it appears that the gray crude iron consists principally of iron, with as much plumbago as it can dissolve in the strong heat of the smelting furnace. They have shewn also, that it deposits part of this addition when cooled in contact with an iron bar immersed in the bath. This separation must be general in the ordinary or gradual way of cooling, whence the gray colour must arise from the blue white colour of the iron mixed with the black of the plumbago. And this gray colour is also in a degree perceived when soft close-grained steel is broken. These circumstances lead me to conclude, that hard steel may in a certain respect differ from that which is softer, by the intimate combination of a larger proportion of plumbago. This accounts for the whiter and more metallic aspect of hardened steel, than of such as is soft. For the former contains less of disengaged plumbago. Hence also we may account for the greater hardness of steel which has been made quite hard, and then let down by tempering to a certain colour, than of steel merely heated to that colour, and plunged in water. For in the first method of hardening, a sufficient degree of heat is given to produce combination between part of the disengaged plumbago and the iron, which in the latter does not take place. If the plumbago be merely sufficient to saturate all the iron at a moderate degree of ignition, the hardness will be considerable; but the steel will be easily degraded to the state of iron by frequent ignition. Such steel in its hard state will be very uniform in its texture, not excessively hard in its temper, but disposed to take a very fine firm edge, which will not easily be broken or injured by violence. These are accurately the properties of the English cast steel, which is of so uniform a nature, as to be distinguished by its conchoidal or glassy fracture. When the dose of plumbago in steel is greater, it will bear a greater heat without degradation, insomuch that it may be



welded like iron. Its hardness will also be capable of a higher degree; and if this degree produced by a stronger ignition be not given, the edge of the tool will never become fine and smooth; and even at this higher degree, with all the advantage of subsequent tempering, it will be less smooth than that of the cast steel, and more disposed to break. Steel of this kind is better adapted for the construction of hammers, vices, hatchets, leather-cutters knives, and other instruments wherein the edge is either stout, or sudden blows unnecessary, or the construction demands frequent heating and welding.

By pursuing this train of reflection, it will follow that, since crude iron differs from steel only in the superabundance of plumbago, it ought to be capable of extreme hardness, if ignited to that degree which is requisite to combine the greater part of this plumbago with the iron, and then suddenly cooled. This is accordingly found to be the case. If the gray crude iron, commonly distinguished by our founders by the name of soft metal, be heated to a white heat, and then plunged in water, it becomes very hard, much whiter, denser, and more metallic in its appearance; and will bear a pretty good edge fit for gravers, for the use of turners in iron or steel. In these tools the angle of the planes which form the edge is about  $45^{\circ}$ . The hardness of this kind of iron is not considerably diminished but by ignition continued for a length of time, which is a fact also conformable to what happens in steel. For the cast steel will be softened nearly as much by annealing to the straw colour, as the harder steels are by annealing to a purple or full blue.

Some of our artists have taken advantage of this property of soft crude iron in the fabrication of axles and collars for wheel-work; for this material is easily filed and turned in its soft state, and may afterwards be hardened so as to endure a much longer time of wear.

The founders who cast wheels and other articles of mechanism are occasionally embarrassed by this property. For, as the metal is poured into their moulds of moistened sand, the evaporation of the water carries off a great portion of the heat, and cools the iron so speedily, as to render it extremely hard, white, and close in its texture. This is most remarkable in such portions of the metal, as have the greatest distance to run from the git or aperture of reception. For these come in contact successively with a larger portion of the sand, and are therefore more suddenly cooled. I have seen the teeth of cog-wheels altogether in this state, while the rim and other parts of the wheel remained soft. The obvious remedy for this defect is to increase the number of gits, and to have the sand as dry as possible or convenient. In other articles this property has been applied to advantage, particularly in the steel rollers for large laminating mills, which Messrs. Vandermonde, Monge and Berthollet have supposed to be an over cemented steel. They are made by casting the gray crude iron in moistened sand, the contact of which gives the hard steel temper to the outside surface, for the depth of more than half an inch. I have no doubt but that the iron-masters pay considerable attention to the quality of the iron, and perhaps to the degree of heat and moisture of the sand in this operation, in order that the hardness may be such as to yield to the turning tool; and I likewise understand, that a considerable number crack longitudinally in the cooling, a loss which in all probability arises from the difference of contraction between the hard and soft parts.

In the experiments of Rinman, a bar of cast iron being placed over the fire of a smelting furnace was almost fused. It was observed in breaking it, that the side nearest the fire had become soft iron to the depth of one sixteenth of an

inch; that the rest was steel, excepting the upper part exposed to the air, which remained in the state of crude iron.

I must refer to the Encyclopedie for a considerable enumeration of experiments relative to the cementation of iron with various materials, and also to such as relate to the return of steel to the state of iron. It appears in general, as might be expected, that iron by a sufficient continued heat in closed vessels, in contact with coaly matter, becomes steel; but that if such matter be not present, the effect does not take place; and even the state of steel, if possessed by the iron, that is to say, its power of hardening by moderate ignition, goes off.

A variety of facts concerning the hardening and softening of steel are collected by M. Morveau, the most interesting of which I shall here subjoin.

The general facts are related under our article IRON. According to Reaumur, that part of the steel which was hottest at the time of immersion in the water will be the hardest; whence it has been thought a fair conclusion, that the hardness of steel is the greater, the stronger the ignition, and the more speedy the cooling. Nevertheless, the celebrated Rinman deduces a very different consequence; namely, that the steel which is naturally the hardest is that which requires the least heat, and that the best temper for each kind of steel is that produced by the lowest degree of heat suitable to that peculiar kind. Hence various methods have been proposed to ascertain the degree of heat most advantageous to any particular sample of steel. They are all reducible to that of igniting one end of a bar to a white heat, and plunging it into water. The hardness of the several parts may then be ascertained by examination.

It appears to me, that the considerations on which the first-mentioned general rule is founded, are rather of a complicated nature. If it be true, as conjectured above, that the hardness of steel depends principally on the intimate combination of its plumbago; it will follow that the utmost hardness any steel is capable of will be produced by a degree of heat sufficient to effect this purpose, and that any superior degree will only degrade the quality of the steel; and consequently, that the general rule will apply only to heats inferior to this maximum. It may also happen, when the mass of water is not considerable, though I doubt the fact when the quantity is large, that the heating of the water, and the production of inflammable air, may so far modify the rate of cooling, as even to render it less sudden than might have happened with an inferior degree of ignition. Lavoisier has remarked, that the conversion of iron into the hard brittle ethiops, when water is decomposed (see WATER), may perhaps be of the same nature as the hardening of steel. There is another fact, which is of great consequence, and may perhaps afford the principal ground for Rinman's apparent exception to the general rule concerning the hardening of steel. Hardness is that property of bodies by which they resist indentation, and rather break than bend, or suffer contusion. It is the opposite to softness. Tenacity, which is very frequently confounded with hardness, is not the property by which they resist indentation, but separation of their parts. It is the opposite to friability or brittleness. Now, that steel, in common language, is said to be the hardest, which unites most eminently the properties of hardness and tenacity. But the effect of heat and sudden cooling is directly opposite in these two respects. Soft steel is the most tenacious, but the least hard. The operation of the temper diminishes its tenacity, and increases its hardness progressively unto the maximum of heat the steel is formed to bear. There will be no difficulty then in conceiving that the best state of steel relative to any particular use, will be at some precise degree between the softest and hardest qualities.



qualities. Thus for springs, much tenacity and moderate hardness are required. For chisels and similar tools which operate by a blow, a greater hardness may be admitted. Razors, knives, and such tools as effect the intended purpose by a gradual stroke, will be still more valuable the harder they are; but even in these the tenacity must not be too much diminished, otherwise the edge will be liable to break. Files are perhaps of all tools such as admit the greatest hardness; but in these, it is far from being the utmost the steel is capable of receiving. It is found that the tenacity of steel is considerably increased by continued hammering to a certain point. But the whole effect of this hammering is taken off by strong ignition. Good steel at a white heat may be rendered so brittle, that it breaks full as easily as a stick of the same dimensions, and its texture is then found to be coarse and large grained. As the subsequent annealing does not restore the effect of the hammering, nor bring the grain of the steel to the state it would have possessed if a lower heat had been used at first; it is evident that the most useful hardness is produced by that degree of heat which is just sufficient to effect the purpose. And accordingly, tools made of cast steel, and intended to sustain a good edge for cutting iron and other metals, are not afterwards annealed, but the ignition is carefully regulated at first. Annealing ought only to be used where considerable softness is required.

Rinman affirms that steel does not harden when cooled in a close cylinder, or even in a vessel purged of air. Not having his work in my possession, I find some difficulty in conceiving how the experiment could be made, so as to obviate all objections relative to loss of time, unless the burning glass and receiver of an air-pump were used. Reaumur also found that a small piece of steel introduced red hot into a tube of glass full of mercury, which was immediately set upright so as to form an ordinary barometer with the vacuum at the top, continued as soft as if it had been cooled in the open air. Do these facts warrant the strange conclusion, that the mere pressure of the atmosphere is concerned in the hardening of steel? It seems, nevertheless, that no other effect of the air could be transmitted to the steel, so instantaneously through a body of water. When we reflect on the effectual modifications which the smallest agitation, or even the presence of light, have upon the arrangement of the parts of solid bodies in crystallization, we shall have less cause for wonder at the confirmation of these facts.

Iron may be hardened to a certain degree by ignition and plunging in water, but this effect is confined to the surface; except, as it very often happens, the iron contains veins of steel. These are no small impediments to the filing and working this material. It sometimes likewise may happen, that the iron may have undergone a process of the nature of case-hardening from the fuel. I have been informed by a workman, that ignited iron suddenly plunged into the soft leather of a shoe, becomes very hard on its surface, which must arise from an instantaneous effect of this kind.

The increase of dimensions acquired by steel in hardening (mentioned in page 414) is such, that in general such pieces of work as are finished soft, will not fit their places when hardened. Rinman found that bars of steel six inches long, six lines wide, and half an inch thick, were lengthened at least one line after hardening by a whitish red heat, which is about one-seventieth of the linear dimensions; and supposing the dilatation to be proportional, M. Morveau computes the bulks to be as 48 to 49. But the cubes of 72 lines and 73 lines are in proportion more nearly as 47 to 50. Various kinds of steel at different hardness must no doubt greatly differ in this respect. The specific gravities as given by

Briffon,

Briffon, p. 366, art. Gravity Specific, afford a much less ratio. Rinman found by his experiments on two different kinds of fine cemented steel, whose specific gravity was 7,991, that one after hardening gave only 7,553, and the other 7,708. These numbers agree sufficiently near with the experiment of the six-inch bar. Yet he once found Styrian steel augmented in density by hardening in the ratio of 7,822 to 7,782. Morveau found, with pieces of steel 28 lines long, that the increase of length by hardening was about the 350th part.

The fineness of grain in hard steel, as exhibited in its fracture, is various according to the quality of the metal, and the temper it has received. The harder the steel the coarser the grain. But in like circumstances, fine steel has the closest grain, and is ever the most uniform in its appearance. Workmen avail themselves much of this indication. In general a neat curve lined fracture, and even gray texture, denote good steel; and the appearance of threads, cracks, or brilliant sparks, denotes the contrary. But the management of the forging and other circumstances of manufacturing will modify these indications; and the steel which is good for some purposes may be less suited to others.

The fluid in which ignited steel is plunged, is of great consequence. All the facts seem reducible to these general conclusions. The hardness will be greater, 1. the hotter the steel is made, provided it be not decomposed: 2. the more considerably its temperature is lowered in the cooling: 3. the shorter the time of cooling: and 4. the more favourable the fire or the cooling material may be to the steel-making process. But the most useful combination of hardness and tenacity will be at a medium temperature in each kind of steel.

With regard to the first particular, little need be said, but that the decomposition of steel in heating will be prevented, and its surface somewhat improved, if it be bedded in charcoal, or the cementing compound, during the application of the heat. The second and third, namely the quantity and suddenness of cooling, require an attention to the doctrine of HEAT, as explained under that article. The cooling will be more sudden and effectual the greater the quantity of heat absorbed in the same time. There are three circumstances which favour this effect, namely, a very low temperature of the body to which the hot steel is applied; that it shall be a good conductor of heat; or that it shall assume either the fluid or elastic state, which always demand a supply of heat for their maintenance. Thus it is found, that steel is more effectually hardened in cold than in warm water, and at like temperatures more effectually in mercury than in water. It may also be remarked, that these two fluids cool the steel by different energies. The water is partly converted into vapour, which carries off the heat, and leaves the fluid much less altered than mercury, which acts by its conducting property. This last fluid, not having evaporated in the process, is found to have acquired a much more elevated temperature by the immersion. Oil is found to harden the surface of steel much more than its internal part, so that it resists the file, but is much less easily broken by the hammer. This effect arises from its imperfect conducting quality, and the elevated temperature it demands to be converted into the vaporous state; to which we may also add, that a stratum of coal is formed round the steel from the burned oil, which still more effectually prevents the transmission of the heat. A remarkable instance of this nature presented itself to my observation in hardening a small piece of steel, two inches long, and a quarter of an inch diameter. At the time of ignition, the water nearest at hand had been used with soap. The steel made very little noise when plunged in the water, and remained hot for a considerable time; but when taken out was found



found to be scarcely at all hardened. It was covered with coaly matter; which being cleared off, and the process repeated with clean water, it became perfectly hard. The heat in both cases was a low red heat, proper for cast steel, which is not intended to be afterwards annealed. I have very little doubt, but that ardent spirit, and the essential oil of turpentine, which are good conductors of heat and very volatile, would render steel very hard, if their inflammability, and the little necessity there is for using them, were not an impediment to their application. Various artists avail themselves of different substances for the immersion of ignited steel. Some use urine, others water charged with common salt, nitre, or sal ammoniac. Tallow and oil are used for such works as are not required to be brittle, though very hard, the reason of which has just been mentioned; but tallow differs from oil in the heat which becomes latent for its fusion; and accordingly, solid tallow is an excellent material for hardening drills and other small articles. It has been found by Reaumur, that saline liquids produce rather more hardness than common water; and in particular, that aqua fortis possesses this property in an eminent degree, probably from its conducting power: the makers of files cover them with beer and common salt, which assist their hardening, and keep the surface from scorifying. The mucilage of the beer supplies a coaly matter; and the fused salt seems not only to form a varnish in the fire and defend the steel, but may also produce cold, by its sudden solution in the water at the time of immersion. Very small articles heated in a candle are found to be hardened perfectly by suddenly whirling them in the cold air; and thin bars or plates of steel, such as the magnetic needle of a compass, acquire a good degree of hardness by being ignited, then laid on a plate of cold lead, and suddenly covered with another plate. These would be unequally hardened, and bend, if plunged in water.

Mr. Duhamel, in the *Encyclopedie*, gives an ample account of the methods of making steel by the ancient way of fusion from the ore, and the more modern way of cementation. We have treated concisely of both under the article Iron, and in this place shall only add a few of the facts noted by this author concerning cementation. The English, who deservedly possess the greatest reputation in this work, have found that every species of iron is convertible into steel by cementation; but that good steel is not to be made except from iron of the best quality, which possesses a certain stiffness and hardness as well as malleability. Swedish iron, as we have before remarked, is the best for this purpose. Mr. Duhamel tried a great number of the irons of France, Sweden and Spain. He found the second to be the best; but he likewise obtained excellent steel, superior to those of Styria and Carinthia, which are the best German steels, by using certain iron made in France. But this iron was selected without fault, and in some instances, the loop or piece at the smelting furnace was fused and forged a second time; a process which, though attended with loss of weight and additional expence, he recommends as absolutely necessary for making steel iron from ores of indifferent quality. The white spathose iron ores afforded him the best iron for the purpose of cementation; and these also are the ores which afford the best steel by fusion, in Styria, Carinthia, and Tyrol. He informs us, that the English use no other cement than mere charcoal, which he also finds perfectly adequate to the purpose; and moreover, that the quality of the steel is not affected by the different kinds of charcoal made use of. He remarks nevertheless, that it may be advisable to add from one-fourth to one third of wood ashes, especially where the iron is not of so good a quality as to afford steel possessing tenacity

tenacity or body, as well as hardness. These ashes, which he used with success, prevent the steel-making process from being effected as rapidly as it would otherwise be, and give the steel pliability without diminishing its hardness. It is remarked, that in the case of this management, the blisters on the surface of the steel are smaller and more numerous. He likewise tried sea-salt. Fifty pounds of salt are sufficient for a furnace of steel of twelve thousand weight. The salt is pulverised, and sprinkled on the bars of iron when put into the furnace. He found that this ingredient likewise contributes to give body to the steel. In the arrangement of the bars in the furnace, the cement is laid one inch thick at the bottom, and half an inch thick between each layer of iron. Our author affirms, that the process would succeed equally well, if the thickness were a little more than a quarter of an inch. The thickness of the bars of iron is indifferent, but there ought not to be a great difference in this respect between bars cemented at the same time. The common thickness is a little more than half an inch. It is not advisable that they should be very broad in proportion to the thickness, as this figure is found to produce flaws and cracks in the direction of the length of the bar. The bars may be square, or their breadth may conveniently be somewhat more than twice their thickness. The fire for cementation must be of considerable intensity, and kept up until the conversion has perfectly taken place, which is ascertained by proof bars, so disposed as to be taken out from time to time. The cementation is finished on the sixth day; that is to say, it commonly lasts five times four-and-twenty hours. And accordingly, the workmen take one of the proofs out on the fifth day, which is forged, hardened, and examined by the fracture. If it break short, and shew no indications of iron, the fire of the furnace is suffered to go out. But if it contains iron, the fire is kept up for twelve or twenty-four hours, accordingly as the quantity of fibrous iron may have proved greater or less in the first proof. A second proof bar taken out at the proper time serves to direct them in the same manner with regard to their operations. By this management, the cementation is continued somewhat beyond the time requisite for the entire conversion. For there is less inconvenience attending a slight degree of excess in the cementation, than would result from a portion of iron remaining in the steel. The charcoal after cementation is as black, and apparently in the same state, as it was before. Mr. Duhamel moistened it, and applied it to the same use a second time. It answered the purpose, but so much more slowly, that he objects to the use of it in manufactories. From this, as well as other circumstances attending the steel-making process, it seems advantageous at least with regard to expedition, that the coals should contain volatile matter. And hence the superior advantages of animal coal, such as the coal of leather, or the hoofs and horns of animals, imperfectly burned, which are used in case-hardening, though they may be less applicable to the longer process of steel-making for various reasons.

Mr. Duhamel advises to have two tilting hammers; one of the weight of one hundred and fifty pounds, and the other half that weight; the first, for the purpose of forging large work, and the latter small bars for cutlers. He recommends another small hammer of about twelve pounds for forging bars still smaller, to make gravers, small files, and the like. The steel must not be heated beyond the degree of cherry red for forging. The tilting hammers should give at least three hundred strokes in a minute.

On this head, I must make a reflection, which perhaps may be of value to the



the manufacturer, though experience certainly affords the only means of determining the utility of proposed alterations in the implements or utensils. When a hammer strikes with a certain momentum, the change of figure produced by the blow will be greater, the more of velocity and the less of mass possessed by the hammer. It seems therefore, in the application of mechanic force, that in most cases the expenditure would prove more profitable, if an extreme velocity were given to a small weight, the face of the hammer remaining the same, than if a larger weight were moved proportionally slower. And so likewise, it should appear, that more work would be done by a certain number of swift blows, than by twice the number with only half the swiftness. When the usual number of strokes is three hundred in a minute, or five in a second, the velocity cannot be considerable, even when assisted by a back spring, or other contrivance. It would therefore at least be worth trying in situations where the power is limited, as in the case of a small stream of water, or steam engine, whether the weights and velocities of the hammers may not be altered with profit. An ingenious mechanic would find no difficulty in contriving a simple apparatus, by which these correspondent alterations might be made at pleasure, accordingly as the nature of the work or other circumstances might demand.

The cast steel of England is made by a process which the manufacturers keep a secret. Mr. Duhamel gives the following account of it: A crucible about ten inches high, and seven in diameter, is filled with ends and fragments of the crude steel of the manufactories, and the filings or fragments of steel works. Magellan affirms, that they buy up broken tools at Sheffield or elsewhere for this purpose. They add a flux, the component parts of which are carefully concealed. It is probable, however, that the success does not much depend upon this flux, which, from the quality of the cast steel itself, may be presumed to be of the nature of a steel cement. This crucible is placed in a wind furnace, like that of the founders, but smaller, because intended to contain one pot only. It is likewise surmounted by a cover and chimney to increase the draft of air. The furnace is entirely filled with coke or charred pit-coal. Five hours are required for the perfect fusion of the steel. It is then poured into long square, or octagonal moulds, each composed of two pieces of cast iron fitted together. The ingots when taken out of the moulds have the appearance of cast iron. It is then forged in the same manner as other steel, but with less heat and more precaution; because more liable to break.

This cast steel is almost twice as dear as other good steel. Mr. Duhamel says, that it is not proper for all kinds of work, particularly those which require much tenacity, as well as hardness to resist violent blows and strains; but it is good for razors, knives, and all toys and small work which require an exquisite polish. It does not seem, however, that the tenacity of this steel is inferior to that of the best of the other kinds, and its uniformity of texture is for many works an invaluable advantage. It is daily more and more used in England, but must necessarily be excluded from many works of considerable size, on account of the facility with which it is degraded in the fire, and the difficulty of welding it, which cannot be done in the common way. I have been informed that the faces of anvils and broad hammers, for the use of silver-smiths and other artists, have been made of cast steel and welded to iron by a particular management, which consisted in substituting between the iron and the steel another kind of steel in the form of filings, or a thin plate. The steel plate intended for the  
face

face was made as hot as could be done with safety, and the iron being at the same time brought to the welding heat, was applied to the steel, and quickly united by hammering.

**STONE.** An indurated hard mass of earth. Stones were formerly distinguished from earths in classification. It does not seem, however, that any useful purpose is likely to be answered by this distinction. For a stone is a mass of earth of considerable magnitude, sand is a collection of small stones, and earth in the pulverulent state may be considered as a fine sand. To the chemist, whose attention is chiefly taken up with the component parts of bodies, these variations of dimension are comparatively of little consequence.

**STONES PRECIOUS.** See PRECIOUS STONES.

**STONES OR CALCULI, FOUND IN THE BODIES OF ANIMALS.** Before the experiments of Scheele and Bergman were made, little was known of the constitution of the stone of the bladder; excepting that alkalis being considered as remedies for this disorder, afforded a slight indication of its acid nature. These two great chemists separately undertook to make a more accurate examination into its component parts.

The stone of the bladder is formed for the greatest part of a peculiar concrete acid, very sparingly soluble in water. If the stone be boiled in this fluid, near three grains out of a thousand are taken up. The solution reddens the tincture of turnsole, but most of the acid is deposited in small crystals.

According to Scheele, water at length completely dissolves it. By destructive distillation it affords volatile alkali, and a brown sublimate, which becomes white by a second sublimation, and is the concrete volatile acid. Seventy grains of the calculus afforded him in this operation twenty-eight grains of sublimate, and there remained in the retort twelve grains of black coal, which preserved its colour in the open air upon a red hot iron.

The same chemist likewise observed: 1. That the vitriolic acid does not dissolve the calculus unless concentrated and boiled, in which case the volatile vitriolic acid flies off. 2. That the marine acid does not act upon it. 3. That nitrous acid acts upon it even without heat; that it dissolves it entirely by the assistance of heat, with the emission of red vapours; and that the elastic fluid which comes over, precipitates lime from water. 4. That this nitrous solution always manifests a disengaged acid; that it leaves a bright red spot upon the skin, and becomes of a blood red colour when much concentrated, which colour disappears on the addition of a few drops of nitrous acid. 5. That this nitrous solution is not precipitated by muriated ponderous earth, and occasions no change in metallic solutions. 6. That this solution is not rendered turbid by the acid of sugar. 7. That the addition of fixed alkali simply produces a yellow colour; that when the alkali is abundant, the mixture assumes a rose colour by digestion, and colours the skin; and that in this case it precipitates martial vitriol of a black colour; vitriol of copper, green; silver, gray; and corrosive sublimate, zinc, and lead, white. 8. That lime water affords a white precipitate with this solution; that this precipitate well edulcorated is soluble without effervescence in the nitrous and marine acids; that the liquor always manifests a disengaged acid, and takes fire when evaporated to dryness; that the precipitate treated in close vessels leaves a black light residue, soluble in acids with effervescence. 9. That the calculus is not attacked by mild vegetable alkali, even boiled, but is very soluble in the caustic alkali; that this solution is yellow, does not become turbid by lime water, is precipitable by all the acids, fixed air not excepted, decomposes metallic solutions,



solutions, and emits a smell of volatile alkali when the fixed alkaline solvent is superabundant. 10. That caustic volatile alkali likewise dissolves the calculus, but the quantity required is large. 11. That a thousand grains of lime water dissolved 53.7 by mere digestion, of which part at least was precipitated by the addition of an acid. 12. and lastly, That all urine, even that of infants, holds a small portion of this matter in solution; that the brick-coloured deposition from urine in fevers is of this nature; that it separates by mere cooling, and is taken up again by heat.

From these experiments several important inferences may be deduced with regard to the composition of the calculus and the properties of its acid. It certainly contains volatile alkali, though in small quantity. Its most considerable ingredient is the acid, which exists ready formed. Scheele admits of the existence of an animal gelatinous matter, though it seems, from the ambiguity attending the combustion or decomposition by nitrous acid or destructive distillation, it must be difficult to ascertain the quantity. It contains no calcareous earth, according to the test of acid of sugar, though Bergman by the application of vitriolic acid to the nitrous solution separated a small portion. Mr. Morveau remarks that it would be wrong to draw general conclusions from the experiments of the Swedish chemists, because other calculi may differ in their properties and component parts; more especially as he was informed by Mr. Tennant of the Royal Society of London, that among the calculi on which he had made experiments, he found some that lost only two thirds of their weight by heat, and the residue formed a transparent glass which became white by cooling. From these appearances, it seems that a considerable quantity of phosphorated lime, with superabundance of acid, was sublimed.

The properties of the acid of the stone of the bladder are, that it is concrete, very sparingly soluble in water, partly decomposable by distillation, and partly sublimable.

This acid, when treated with the nitrous acid, is not simply dissolved. The mass which remains, as Bergman informs us, after evaporation to dryness is very different from the concrete acid. It is of a dull red colour; attracts the humidity of the air; a very small portion of it gives a rose colour to water; in a word, it stains the skin, bones, and even glass, like the nitrous solution. This great chemist remarks, that these phenomena are much more likely to arise from a change in the animal acid than from a residue of the nitrous. But Morveau justly adds, that the nitrous acid is itself decomposed, and produces a higher degree of acidification in the animal matter, by the communication of vital air in the same manner as that principle produces a change in the marine acid.

This acid unites to earths, alkalis, and metallic calces. It appears to prefer the alkalis to the earths, but yields these bases to the weakest acids, even fixed air; in which particular it differs from all the other acids but the Prussian, with which it cannot be confounded.

M. Fourcroy has inserted in the sixteenth volume of the *Annales de Chimie* a comparative analysis of the different animal and vegetable concretions intended to form the article *calculs* in the *Encyclopedie*. The first part of this memoir is contained in the number for January 1793. It chiefly relates to animal concretions. The remainder has not come to hand, on account, as I suppose, of the interruption of communication produced by the troubles in France. One of the greatest difficulties this chemist found, consisted in making a collection of the different concretions in the human body, and still more with regard to the calculi

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in the different species of animals. In order therefore to communicate a notion of the imperfect state of science in this respect, and the importance of the necessary researches, he speaks rapidly in the alphabetic order of the principal calculi hitherto known. Some facts and even some analyses peculiar to himself are inserted; but the greater number of articles exhibit little more than an indication of what remains to be done.

The biliary calculi are of two kinds, relative to the proportion of their ingredients. One kind is entirely composed of a foliated brilliant crystalline substance, analogous to spermaceti; the others, with a greater or less quantity of this substance which constitutes the basis or nucleus, contain the thickened bile or extract of bile, in the midst of which the first-mentioned substance appears to have irregularly crystallized. We are indebted to M. Fourcroy for what we know concerning the biliary calculi, but much remains yet to be done in this respect. He states a part of the objects of research by asking, How is the abdominal fat converted into a substance resembling spermaceti? What is the cause and mode of this conversion? By what signs can we ascertain its existence in men? What are the indications of this disposition in the biliary passages; and particularly, What are the means of opposing it? What difference may exist between the human biliary calculi and those of other animals? It is known that oxen and sheep are subject to this disorder. The butchers find biliary stones in the intestines and gall bladder of oxen, particularly at the end of autumn and during the winter. It is said that they are used as a pigment; but no comparative analysis has yet been made to distinguish them from the human gall-stones.

The liver is often filled with hard and solid concretions, which are the consequence of obstruction. These have not yet been examined. Fourcroy seems disposed to conjecture that they may be of the same nature as that of the concretions found in the bladder.

Intestinal calculi are those which are found in the intestines of man or other animals, whether discharged from other organs or viscera, or formed in the intestinal canal. In man they are almost always gall-stones, and are ordinarily discharged by the anus. Calculi formed by the induration or crystallization of the contents of the intestines, are extremely rare in the human system; but much more common in animals. Our author examined one of these concretions taken from the intestinal canal of a horse. Its colour was gray; it appeared to be formed of rays diverging from the centre to the circumference. Its figure was round, considerably regular; its diameter five inches, and its weight five pounds. When sawed in half, it was seen that its parts were so arranged round a common centre, as to diverge in all directions, and form a sphere of eighteen inches circumference. The centre of this sphere exhibited certain cavities which contained fragments of vegetable matters, such as straw, hay, and oats; which emitted the smell of these substances already altered.

M. Fourcroy examined this substance by treatment with water hot and cold, with the pure mineral alkali, by the action of heat, the three mineral acids, the aerated marine acid, destructive distillation, and distillation with charcoal. For the sake of brevity the results are here omitted; but they produce the conclusion that the calculus was a triple salt, composed of about two parts phosphorated magnesia, one part phosphorated volatile alkali, and one part water, besides certain traces of vegetable and animal admixture.

M. Fourcroy offers several conjectures relative to the formation of this concrete substance. He demands whether its principles were formed in the viscera of the



horse; and on that supposition, whence did they derive their elements? for they themselves are compounds. By what means did the magnesia, a substance so rarely met with among animal matters, become part of this compound? Can it be supposed to have originated in the entrails of the animal? and if so, by what process? Is there any ground for the loose and remote hypothesis, that it may be a modification of lime, which is so universally diffused in animals? With regard to the phosphoric acid, though we are far from possessing a good ground of estimate of its quantity in the animal œconomy, yet it is easy to conceive that it may have been collected in the intestines, and united in a course of time with the magnesia and volatile alkali. Perhaps the magnesia may have been given to the animal as a remedy for some intestine disorders. This suspicion appears the most probable to Fourcroy; though it seems, according to him, to include the supposition that the magnesia must have remained a long time in the animal, and prevented its ordinary evacuations.

Every concretion formed in any part of the body is called a calculus or stone by medical writers. There are two kinds of muscular calculi or concretions which originate in the midst of the fleshy fibres. The one are merely ossifications of tendinous fibres, which take place in old animals, at the time when the extremities of tendons and the sides of vessels themselves are ossified. It is an abuse of terms to call these calculi. The other kind of muscular concretions of a granular, angular, or irregular figure, which are met with, though indeed rarely, in the internal parts of the muscles themselves, between the fleshy masses, and which are most frequently found after long continuance of gout: these have not been analysed. It is probable that they are of the same nature as those found in gouty articulations, and analogous to the solid matter of bones. Fourcroy was not able to procure a single muscular calculus during the course of twelve years enquiry.

Anatomists have frequently found solid concretions in the human pancreas. They have not been analysed. Nothing is more common than to find several small stones in the pineal gland of the human head. This fact is generally known to anatomists; but either on account of their smallness, and the difficulty of procuring a sufficient number, or the little attention which has been hitherto paid to the utility of chemistry in the philosophy of animal bodies, no examination has yet been made of this interesting object.

It is not uncommon for old persons who have been long subject to arthritic affections, to expectorate, by coughing, small irregular calculi, which Mr. Roering affirms to be of the same nature as the basis of bones; that is to say, phosphorated lime.

Stones are formed in the kidneys, which are the natural filter of the urine. The human species is very subject to this disorder. When the renal calculi are small, they are carried along with the urine through the urethers, and evacuated under the name of gravel; but when they are retained they produce more serious evils, for which medicine at present possesses no remedy. This concretion in man is of the same nature as the stone of the bladder, as Fourcroy found by examination.

The singular properties of the urine of the horse are well known. It is much more charged with matter that subsides than urine of men, and hence it becomes turbid at the very instant of its emission. The powder which falls down from the urine of the horse is for the most part chalk, as Fourcroy asserts, whereas that which is precipitated from human urine, especially at the end of attacks of illness, is the acid of the stone of the bladder. On examination of the renal calculus  
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of a horse, its component parts were found to correspond with those of the urine of the animal.

The salivary calculi are not rare, particularly in the parotid and sublingual glands. Medical writers abound with observations relative to these concretions, but nothing chemical has been done respecting them. They have been supposed to be of the same nature as the tartar of the teeth, which Fourcroy has ascertained to be phosphorated lime.

Different species of calculi are found in the stomach of man, particularly biliary concretions, stony and stratified concretions, and balls of hair or fibres agglutinated by a concrescible lymph. Many facts of this nature are extant, but none of the narratives exhibit materials to ascertain the intimate nature of these concretions.

The property of forming calculi is observed likewise in vegetables. Several botanists have described these vegetable concretions, particularly in the cocoa, the palm, &c. There are several in the collection of Jussieu. Fourcroy saw some which were round, white, polished like ivory, and apparently very hard. He could not ascertain their nature, on account of their scarcity and dearth. They are called vegetable bezoar, and the credulity which accompanies all the prejudices of medicine has extolled them as very powerful remedies.

It is well known that several fruits, more especially pears, are very subject to contain a quantity sometimes considerable of granulated, irregular, hard concretions which are known by the name of stones. Mr. Vauquelin has made a number of experiments upon these, which prove that they are of the same nature as wood.

**STORAX.** The most fragrant of the solid resins, and indeed of all the known vegetable substances, is storax or styrax, obtained from a tree of the same name, said to grow most plentifully in Syria, Cilicia, and Pamphilia. America likewise produces storax-trees, but not that particular species which affords the officinal resin. The true storax-tree has leaves like those of the quince, and hence is named by Caspar Bauhin and Tournefort, *Styrax folio mali cotonei*: its flowers are white, in shape somewhat like a funnel, divided into several segments about the edges: the fruit is about the size of a hazel-nut.

The fine storax, called red storax, or storax in the tear, is the pure native juice, flowing from incisions made in the trunk of the tree. This is very rarely to be met with. The common storax is supposed to be in part an artificial composition, mixed with a considerable portion of the genuine resin. Of the production however of this concrete we have no satisfactory account. That it is not an artificial composition may be judged from hence; that notwithstanding its large admixture of saw-dust, it is more fragrant than the pure storax in the tear, and its fragrance is exactly of the same kind. Some resinous bodies indeed discover a greater degree both of smell and taste, when diluted with other substances of themselves inodorous and insipid, than in their pure state: but the pure resin extracted from common storax by spirit of wine, is still more fragrant than the storax itself, or the resin prepared by the same means from storax in the tear.

It seems probable, that the pure storax is the juice which concretes upon the tree, and which has lost in the drying its more subtle odoriferous parts; and that the common storax is the juice received immediately in vessels, and mixed with saw-dust enough to thicken it; the shops requiring under the name of storax a solid



solid or consistent mass, and evaporation being found to dissipate its fragrance. Neumann observes, that he cannot conceive for what other purpose the woody matter could be added; for it is too easily distinguishable to have been intended as an imposition.

The storax-tree is said to grow spontaneously, not only in the eastern countries, but in Italy; whether it yields any resin there, we have no account. It scarcely bears the winters of our climate without shelter.

The common storax was formerly brought to us inclosed in reeds or canes, whence its name *styrax calamita*: at present we meet with it in large cakes or loaves, of a reddish brown colour, softish, and as it were unctuous to the touch, yet brittle and friable, and of an extremely pleasant sweet smell.

Out of an ounce of common storax, rectified spirit of wine dissolved six drams; from the residuum, water extracted half a dram of gummy matter; the rest was almost mere saw-dust. Another ounce of the same storax, treated with water at first, gave two drams of extract; after which it yielded with spirit four drams of resin, the saw-dust remaining as before.

Pure spirit elevates in distillation very little of the smell of the storax: the distilled water is notably impregnated with its fine flavour, but no separable oil is obtained. To determine this last point more fully, Neumann distilled eight ounces of storax with sixteen ounces of water in a glass retort. No appearance of oil could be perceived till the water was almost all drawn off, and the remaining storax began to grow dry and scorched: then arose a fine subtle oil, weighing two scruples, together with nine drams of an empyreumatic liquor: presently succeeded two drams and a scruple of thick butyraceous oil, and afterwards two ounces one dram of an empyreumatic oil, which had nothing of the smell of the storax, along with five drams of an acid spirit: the residuum weighed two ounces and seven drams. The butyraceous oil being washed with warm water, and the water set by in a cold place, a small portion of saline matter separated, similar in appearance to the flowers of benzoin.

Though rectified spirit distilled from storax brings over little or nothing of its smell; we may nevertheless obtain a spirit pretty strongly impregnated both with the smell and taste of the storax, by previously mixing the resin with twice its weight of salt of tartar, and drawing over a rectified spirit of wine from this mixture. The strongest and most fragrant principle, separable from storax, is the subtle, slightly empyreumatic oil, which arises first in the distillation of it.

In the shops, we meet with a fluid resinous substance, called *styrax liquida*. This is said by some to be extracted by expression from the bark of the storax-tree; by some from the leaves, or the leaves and bark together; and by others, to be a composition of turpentine, oil, wine, and a little solid storax. This last account is the most probable. Neumann informs us, there was a person in his neighbourhood (Berlin) who prepared some hundred weights every year, and was said to employ chiefly common resin.

Lewis in a note on this passage observes, that the genuine liquid storax is obtained not from the tree which yields the solid storax, but from one of a different genus, though usually called by the same name. That which yields the solid is distinguished by the epithet quince-leaved, and that which yields the liquid by that of maple-leaved-storax.

The maple-leaved storax-tree is a native of Virginia, Mexico, and some other parts of America, and is easily naturalized to our own climate. A resinous juice approaching

approaching in fragrance to storax, exudes upon the surface of the leaves, and may be extracted more perfectly by spirit of wine: the process by which the juice is procured abroad has not been tried with the trees raised here.

Liquid storax and liquid amber are said to be both obtained from this one tree, the first by boiling the bark or branches in water, the latter by making incisions in the trunk. Mr. Petiver gives an account, in the Philosophical Transactions, of the preparation of liquid storax, as practised in the island Cobros in the Red-Sea, from a tree (which probably is no other than this) called by the Turks and Persians, *Rosa Millos*. The bark is annually cleared off, and boiled in sea water to the consistence of bird-lime. The resinous matter, which floats upon the surface, and contains a considerable portion of the substance of the bark, is taken off, liquefied again in boiling water, and passed through a strainer. The purer part which passes through, and the more impure which remains on the strainer, are both sent to Mocca, from whence they are sometimes, but very rarely, brought to us. The first is of the consistence of honey, tenacious like turpentine, of a brownish colour, an acrid aromatic unctuous taste, and a smell approaching to that of solid storax, but so strong as to be disagreeable. The impure sort is full of woody matter, and much weaker in smell.

The liquid amber, or juice which issues from incisions in the trunk, is at first of the consistence of thin turpentine, but by long keeping grows hard and brittle. It is of a yellow colour, inclining to red, of a hot aromatic taste, and a fragrant smell, not unlike that of storax heightened with a little ambergris. It was formerly much used as a perfume, but is at present scarcely known in the shops.

Four drams of liquid storax yielded, with rectified spirit of wine, three drams and one scruple of resinous extract; from the remaining two scruples, water took up only a few grains: the distilled spirit smelt a little of the resin. In distillation with water, an essential oil arose, similar in flavour to oil of turpentine, or the *oleum pini*. By distillation in a stronger fire, instead of a clear empyreumatic oil, what came over was almost mere pitch. These experiments are a sufficient proof that the common liquid storax is an artificial compound.

**STRONTIONITE.** In the second part of the Philosophical Transactions for 1794, there is an account of a mineral substance thus denominated from the place Strontion in Scotland, where it is found in granite rocks, accompanied by galena and witherite, by which last name, I suppose, Mr. Schmeisser, the author of the analysis, means the native aerated ponderous earth.

In all the specimens this author had seen, he could not discover any regular crystallized figure. The specimen which he submitted to experiment was in solid masses, apparently composed of long fibres, closely adhering together and disposed in radiations; its colour was an asparagus green, deeper towards the centre of the mass; when broken, the surface was a little shining in certain directions, the fragments rather bar-like, and somewhat brittle.

Some specimens exhibit only light shades of this colour, and appear to be composed of long thin bars, which are often separated from each other towards the extremity.

The specimen examined was semi-transparent, but the most of it rather inclining to opaque. A hard knife scratched it, but it could not be scraped. Its specific gravity was 3,586 at 60° of temperature.

The first experiments which pointed out a distinction between the basis of this stone and the ponderous earth of Scheele, were made by Dr. Crawford's desire, by his assistant Mr. Cruikshank, and were afterwards repeated by himself. The

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account of these is inserted in the second volume of the Medical Communications, by reference to which Mr. Schmeisser very properly does justice to the original discoverers.

Mr. S. found, 1. that the powder of strontionite was not acted on by boiling water, 2. nor by the vitriolic acid; 3. but the nitrous and marine acids feverally and entirely dissolved it with strong effervescence; the elastic fluid which escaped, was pure fixed air. 4. Diluted vitriolic acid, added to the diluted nitrous and marine solutions, threw down a white precipitate. 5. Before the blow pipe, a piece of the strontionite did not crackle, nor split asunder, nor did it melt even when exposed to white heat; but it discovered a very bright phosphorescent light, became more brittle, lost its greenish cast, and then was partly soluble in water. A long continuance of the white heat deprived it of very little of its weight, and it still effervesced with acids. 6. With borax and with soda, it melted with ebullition, but neither a blue nor a green colour was exhibited by fusion with the former. 7. Fluid volatile alkali did not extract any blue colour from the powdered substance, nor when added to the acid solutions. The solutions in the marine and nitrous acids were colourless. A piece of paper dipped in the nitrous solution, burned with a red flame. 8. The Prussian alkali added to a saturated solution threw down a very slight quantity of blue precipitate. 9. Acid of sugar added to the diluted solution afforded a very slight precipitate. 10. The remaining liquid of the foregoing experiments was mixed with vitriolic acid, until no more precipitate took place; after which the remaining filtered liquor afforded no earth, when purified potash was added to saturation. 11. The saturated nitrous solution afforded crystals by evaporation, which were permanent in the air, and exhibited triangular and sexangular plates. 12. The saturated marine solution exhibited one vaporation long six-sided prisms, which have the broad alternating with the narrow sides, and terminate in obtuse trihedral pyramids. This was observed by Dr. Crawford, who also found that the salt formed of the substance with acids dissolved in water, produced five times more cold than the salt from the barytes in the same acid; that the salt formed by marine acid and this substance, was much more soluble in warm water than in cold, whilst the muriat of barytes is nearly as soluble in cold as in warm water; that one ounce of distilled water dissolves three times as much of the muriat of strontionite as of the muriat of barytes, which makes a distinction between the basis of this substance and the barytes. 13. Nitrous acid added to the marine solution of strontionite occasioned a decomposition. 14. The earth was procured in a distinct state by solution in marine acid, precipitation by diluted vitriolic acid, subsequent drying, and decomposition by means of heat, with purified potash, washing with water, and calcination. The quantity of fixed air contained in this earth was then proportionally ascertained by solution in acid. Mr. Schmeisser then found, that a hundred grains of specific vitriolic acid, by which I suppose he means the particular acid he made use of, required 133 grains of the pure earth for saturation, but that 130 grains of pure ponderous earth were required for the same purpose; that a hundred grains of nitrous acid required 94 grains of this earth, but 120 grains of the ponderous earth, for its saturation; and that 100 grains of marine acid required 56 of this earth, but 96 of the ponderous.

Hence Mr. Schmeisser concludes, 1. That the native mineral contained no saline matter. 2. That it contained fixed air; and 3. An earth similar to the ponderous earth in its habitudes with the vitriolic acid. 4. No water of crystallization. 5. No cobalt nor copper. 6. A small portion of iron. 7. Some calcareous earth.

8. No argillaceous nor magnesian earth; and 9. That the earthy basis is of a different nature from ponderous earth.

In order to ascertain the quantity or proportion of component parts of this substance, he dissolved 100 grains in acid, which yielded 30 grains of fixed air. Half a grain of calcareous earth was precipitated by acid of sugar, and the remaining solution yielded by decomposition 68 grains of the peculiar earth, which may be called strontion earth. The remaining weight may be accounted for from the substance which gives it the colour, which from comparative experiments Mr. Schmeisser supposes to be phosphorated iron and manganese.

The substance with which it was accompanied, was crystallized in six-sided prisms, with pyramids, colourless, semi-transparent, rather opaque towards the basis, and less hard than the other substance. By analysis it was found to contain seventy grains of ponderous earth, fifteen grains of fixed air, and twelve of calcareous earth.

**SUBLIMATE, CORROSIVE.** There are several ways of preparing corrosive sublimate. The most common way is, by mixing equal parts of dried mercurial nitre, decrepitated common salt, and calcined or white martial vitriol; putting this mixture into a matrafs, of which two thirds must remain empty; immersing the mixture into a sand bath, and heating it gradually till its bottom is made red hot. The vitriolic disengages the marine acid from the soda: the soda again separates the nitrous acid from the mercury, which has robbed it of part of its vital air; after that the marine acid combines with the calx of mercury, and forms corrosive mercurial sublimate, which rises in flat pointed crystals, that fix on the upper part of the matrafs. The nitrous acid is dispersed in nitrous gas; the residue is reddish or brown, and contains calx of iron and common Glauber's salt, formed by the combination of the vitriolic acid with the base of the marine salt. In Holland, this salt is prepared in the large way by triturating together equal parts of mercury, common salt and vitriol of iron, and exposing the mixture to a strong heat. In this way of preparing corrosive sublimate, the vitriolic acid, disengaged by heat from the vitriol of iron, appears to convert the simple into aerated muriatic acid; for no other but this last acid could dissolve all the mercury employed on the occasion. Corrosive mercurial sublimate may be likewise obtained by subliming a mixture of vitriol of iron, common salt, and mercurial precipitate, by fixed alkali, or any other kind of mercurial calx.

Boulduc has given a very good process for preparing corrosive mercurial sublimate: but Spielman remarks, that it was before suggested by Kunckel in his Chemical Laboratory. It consists in heating in a matrafs equal quantities of vitriolic salt of mercury, and decrepitated common salt. Corrosive sublimate is volatilized, and what remains is only Glauber's salt. This mode of operation affords a very pure corrosive sublimate; whereas that which we obtain in commerce, and even that which is prepared in the small way with vitriol of iron, always contains some mixture of iron. Boulduc's process is both easier and less expensive. It likewise proves, that the vitriolic acid possesses the property of aerating the muriatic acid in these circumstances. M. Monnet informs us, that he obtained this salt also, by treating in a retort very dry common salt with mercurial calx precipitated from the nitrous solution of mercury by fixed alkali. In all these processes for preparing corrosive mercurial sublimate, the operator should beware of breaking the vessel containing the sublimate till it be perfectly cool, lest he suffer from the vapours of the salt. Lastly, there is yet another and more expeditious way of



preparing corrosive mercurial sublimate: it consists in pouring aerated muriatic acid into a solution of nitrated mercury, and evaporating the mixture slowly: when the nitrous acid is disengaged, the liquor affords, by cooling, crystals of the corrosive mercurial salt. There is reason to think, that when Scheele's aerated muriatic acid becomes better known, apothecaries will prepare corrosive mercurial sublimate, either by this last process or by simple solution.

Corrosive mercurial sublimate is a neutral saline substance, which well merits the attention of chemists and physicians. It possesses a number of valuable properties, which Fourcroy has enumerated. It has a very caustic taste. When but the smallest quantity touches the tongue, it leaves for a long time after a stiptic and metallic impression, which is very disagreeable. This impression extends even to the larynx, closing it spasmodically; and the effect remains long, particularly on persons of very delicate nerves. This salt acts in a still more sensible manner on the coats of the stomach and the viscera. When suffered to act upon them for some time, it corrodes them so as to destroy their substance: it is of consequence one of the strongest poisons known. The causticity of corrosive mercurial sublimate appears to depend on the state in which the mercury exists in the salt, as has been very ingeniously explained by Macquer. It cannot, as some authors have imagined, be ascribed to the muriatic acid; for the quantity of the mercury is more than three times as much as that of the acid. Accordingly, it has been observed by Rouelle, that this salt communicates rather a green than a red colour to syrup of violets. The taste too of corrosive mercurial sublimate is much stronger than that of the muriatic acid. A person may take a dram of muriatic acid diluted in water, without suffering any harm: whereas a few grains of mercurial muriate taken in the same quantity of water are a certain poison. Bucquet thought this excessive sapidity to depend on the combination of the two bodies which compose this salt. One of his strongest proofs was drawn from that law of the affinity of composition by which it is established, that compounds possess new properties entirely different from those of the bodies of which they are compounded.

Corrosive mercurial sublimate suffers no sensible alteration from light. Heat volatilizes and half vitrifies it. When exposed to a strong heat in the open air, it is dissipated in a white smoke, the effects of which are very energetic, and very noxious to the animal economy. When heated slowly and by degrees, it is sublimed in a regular crystalline form. Its crystals are prisms, so compressed, that it is impossible to determine the number of their faces. They terminate in very acute points; and have been with good reason compared to the blades of poniards thrown very confusedly together. Fire does not decompose this salt; it suffers no alteration from air. It dissolves in nineteen parts of water, and crystallizes by evaporation into flat prisms, very acute at their extremities, resembling those obtained by sublimation. The spontaneous evaporation of its solution afforded both Fourcroy and M. Bucquet several times oblique-angled parallelepipeds, with their extremities truncated slopewise. M. Thouvenel has obtained that salt crystallized in hexahedral prisms a little compressed.

Barytes, magnesia, and lime decompose corrosive mercurial muriate, causing it to yield a precipitate of calx of mercury. The phagedenic water used by surgeons as a corrosive, is prepared by adding half a dram of this salt in powder to a pound of lime-water; a yellow precipitate is formed, which renders the liquor turbid, and it is employed before the precipitate subsides. The fixed alkalis separate from corrosive mercurial sublimate an orange-coloured calx, which,

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when suffered to settle for some time, acquires a deeper colour. Volatile alkali causes this salt to yield a white precipitate, which however soon assumes a slate colour.

The acids of the alkaline neutral salts produce no alteration on corrosive mercurial sublimate.

This salt contracts an intimate union with sal ammoniac; but neither of them is decomposed. Either by sublimation, or by crystallization, it forms with it a very singular saline compound, which the alchemists valued highly, and called alembroth salt, salt of art, salt of wisdom, &c. The sal ammoniac renders the corrosive sublimate very soluble; for, according to Baumé, three ounces of water, containing nine drams of the former salt, dissolve five ounces of the latter. This last solution is effected by the help of heat; and when it cools, the salt subsides into a mass. With this salt a preparation is made up which is called white precipitate. It is prepared by casting into a solution of a pound of sal ammoniac an equal quantity of corrosive mercurial sublimate in powder. When this salt is fully dissolved, a solution of mild vegetable alkali is poured into the mixture, and produces a white precipitate: this precipitate is washed, formed into little balls, and dried in the air. In this operation the pot-ash disengages the volatile alkali; which in its turn precipitates the mercury in a white calx. This precipitate becomes yellow when exposed to heat, or even to light.

Corrosive mercurial sublimate is altered by inflammable air. Sulphur produces no change on it, but liver of sulphur decomposes it as well as the other solutions of mercury: the immediate product of this decomposition is a black precipitate, which results from the combination of the sulphur with the mercury. Most of the semi-metals are capable of decomposing this salt: and each of these instances of decomposition is attended with peculiar phenomena.

When two parts of corrosive mercurial sublimate with one of arsenic are distilled by a moderate heat, there passes into the receiver a matter of the consistency of oil, and transparent, of which one part is very soon condensed into a kind of white jelly, improperly called corrosive oil, or butter of arsenic. If the heat be continued after this product has passed off, running mercury is obtained; and by this process we may attain an accurate knowledge of the principles of corrosive mercurial sublimate. This marine combination of arsenic does not appear to be susceptible of crystallization; it melts by a moderate heat, and its taste is so caustic that it instantaneously destroys our organs. It dissolves in water, by which it is partly decomposed: we are ignorant of its other properties. It cannot be obtained with calx of arsenic; because when that semi-metal is already saturated with vital air, it cannot disengage mercury from its combination with the muriatic acid, by absorbing that principle.

The effects of nickel, cobalt, and manganese, on corrosive mercurial sublimate, have not yet been examined. As to bismuth, antimony, and zinc, those three semi-metals decompose this salt very readily. By distilling two parts of corrosive mercurial sublimate with one of bismuth, we obtain a thick fluid substance, which congeals into a kind of greasy mass that melts on being exposed to heat, and yields a precipitate when plentifully washed: in a word, this compound is a solid marine salt of bismuth. Doli, quoted by Fourcroy, who has given an account of this process in the History of the Academy for the year 1713, tells us, that when this butter of bismuth is several times sublimed, there remains



in the vessel a powder coloured like oriental pearls, very soft and gluey: he proposes the use of this powder in painting.

When twelve ounces of antimony are completely mixed with two pounds of corrosive mercurial sublimate, the mixture gives out heat; a circumstance which proves that these two bodies act rapidly on each other. On distilling this mixture by a moderate heat, we obtain a thick liquor which is fixed in the receiver, and often even in the neck of the retort, into a white mass called butter of antimony. The quantity of this sublimated marine combination of antimony is commonly sixteen ounces and a few drams. The residue consists of mercury and a gray powder of antimony, which swims on the surface of the metallic fluid. On continuing the distillation after the butter of antimony has passed into the receiver, and using a new receiver, we obtain running mercury; but it is contaminated with a little of the butter of antimony, as that substance cannot be entirely taken away from the neck of the retort. Mr. Baumé, who has given a good account of this operation, says, that by this process twenty-two ounces of running mercury may be obtained, one ounce of antimony in powder mixed with mercury, and six drams twenty-four grains of antimony fused in the retort. The antimony is partly calcined: it affords a red and partly white calx which is sublimed. In this instance, the antimony is calcined by the vital air separated from the mercurial calx, and combines with the muriatic acid to form butter of antimony. This decomposition likewise takes place when crude antimony is employed. By distilling one part of that mineral in powder, with two parts of corrosive mercurial sublimate, sublimated muriate of antimony is obtained; but the residue, instead of containing running mercury, is a combination of mercury with sulphur. That combination may be sublimed by a very strong heat into red needles, which are improperly called cinnabar of antimony.

Sublimed butter of antimony, or the combination of the aerated marine acid with antimony, is not produced unless when the semi-metal attracts from the mercury the vital air which it contains; as has been already observed of arsenic. This compound is in a crystalline form. It crystallizes into very large parallelopipeds. It is so caustic that it instantly destroys our organs, and burns vegetable matters. It is very liable to alteration by the contact of light. It melts with the most moderate heat, and becomes fixed by cooling: it is this property which has procured it the name of butter of antimony. It readily loses its whiteness, and becomes coloured. It may be rectified by distillation. It attracts the moisture of the atmosphere, by which it is again dissolved into a thick and seemingly oleaginous fluid: in water it is dissolved only in part; for the greatest portion of it is decomposed by that fluid. When butter of antimony is cast into distilled water, it immediately gives a very copious precipitate, which is commonly called emetic powder, or powder of algaroth, from the name of an Italian physician who used it as a medicine. It has likewise been improperly called mercury of life. This precipitate is a calx of antimony strongly purgative and emetic, even when given in very small doses of three grains and a half to the dose. In order to render it very pure, it must be repeatedly washed in distilled water. It differs in possessing these properties from the other calces of this semi metal, which are far from acting in so energetic a manner on the animal economy. A portion of this calx is dissolved in the water, in which butter of antimony is washed, by means of the acid which mixes with the fluid. We have an opportunity of observing this fact on pouring a little alkali into that li-

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quor: a white precipitate is produced in considerable abundance: and butter of antimony therefore appears to owe its property of being decomposable in water to its containing an excess of this calx: and its forming into a solid mass may be attributed to the same cause. Sublimed butter of antimony dissolves with heat and effervescence in the nitrous acid. From that solution there is disengaged a large quantity of nitrous air, which excites a considerable motion in the mixture; the muriate of antimony disappears, and the liquor appears of a reddish yellow colour. This is a solution of calx of antimony in the nitro-muriatic acid, or aqua regia. It very soon deposits the calx of antimony in the form of a powder, and even of a white magma.

If the solution of butter of antimony by the nitrous acid be evaporated to dryness as soon as made, it yields a very white calx: this is diluted with a quantity of the same acid equal to its own weight, and again evaporated: the powder is yet a third time mixed with the same quantity of nitrous acid, and evaporated to dryness: it is then treated in a crucible, which is kept red-hot for about half an hour, and after that suffered to cool. The calx now taken out of the crucible is white above, and rose-coloured on the under part. The two portions are then mixed, and form by their mixture what is called bezoar-mineral. Macquer considers this medicine as a perfect calx of antimony, and thinks it to be the same with diaphoretic antimony. Lemery, however, who has given an accurate description of this preparation, advises us to calcine it till it have scarce any acidity; but wishing it to retain some acid, which must certainly change the properties of the calx of antimony.

Corrosive mercurial sublimate is decomposed by fire, as has been asserted by Pott, and as Fourcroy found by repeated experiments. If you distil in a glass retort a mixture consisting of two parts of this salt with one of zinc in filings, or coarse powder, a white and solid salt ascends from the mixture, and is crystallized in small needles joined together, in a form resembling the little bundles of which stalactites consist. This marine combination of zinc emits a thin smoke when it is taken out of the receiver: it melts by a moderate heat; is coloured by inflammable vapours; and lastly, is partly decomposed in water like sublimated butter of antimony.

**SUBLIMATE RED.** See **PRECIPITATE RED.** If a greater heat be applied to red precipitate than was required to produce the red colour, it becomes decomposed, and the products are vital air and running mercury. But if the application of the heat be sudden, the red compound is volatilized for the most part without decomposition. This has been called red sublimate; but it is very seldom prepared or used.

**SUBLIMATE SWEET,** or mild Mercurial-Calomel of the London College. The most singular property which corrosive mercurial sublimate exhibits in regard to the alterations which it suffers from metallic substances, as well as the most important property which it possesses, is its power of combining with running mercury. When saturated with that metallic fluid, it loses most of its properties, particularly its taste and solubility. The old way of producing this combination was, by triturating in a glass mortar corrosive mercurial sublimate with running mercury, adding the mercury by degrees till it refused to unite with the mercurial sublimate. Lemery and Baumé have observed, that the salt takes up a quantity of mercury equal to about three-fourths of its own weight. The mixture was then put into small phials, two-thirds of each of them being left empty, and sublimated three times successively. Care was taken to sepa-

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rate at each time a white powder, which is found above the sublimated matter, and is very corrosive. This product is called sweet sublimate, *mercurius dulcis*, or *aquila alba*. Its insipidity, its crystalline form, and its being almost totally insoluble, distinguish it from corrosive mercurial sublimate. The crystals which it affords by slow sublimation are tetrahedral prisms terminating in four-sided prisms. We often find among them two very long tetrahedral pyramids, joined at the base, and forming very acute octohedrons.

The process for preparing sweet mercury here described is attended with several inconveniences. To triturate corrosive mercurial sublimate with running mercury till the mercury be entirely confounded with the mercurial salt, is a very tedious and a very difficult task. A very minute acrid dust arises from the mixture while it is triturated; and the operator must bind a cloth over his mouth and nose to secure himself against the dangerous effects of that dust. The mercury is never entirely incorporated with the mercurial sublimate; and the sublimation is very slow. Baumé advises to pour a little water on the matters as they are triturated. That fluid assists the trituration, and hinders the saline dust from rising. He likewise employs levigation, which contributes greatly to make the mercury incorporate with the salt. Lastly, to make sure of obtaining mild mercurial sublimate, without the least mixture of corrosive, Zwelfer, Cartheuser and Baumé propose to pour on mild mercurial sublimate, after it has been once sublimated, a quantity of hot water, to dissolve the corrosive sublimate, and then dry the salt, which is after this found to be much milder than before. Cornette, to hinder the volatilization of the corrosive mercurial sublimate triturated with the mercury, proposes to make use of nitrate of mercury precipitated by ammoniac, which unites with corrosive mercurial sublimate much more readily than running mercury. But as this calx is not so pure as mercury, we cannot depend so much on the virtues of the preparation into which it enters. Bailleau, an apothecary in Paris, has given the Royal Society of Medicine a process for preparing mild mercurial sublimate, without being exposed to any of those accidents which render the preparation of it in the common way so very dangerous. This process consists in forming a paste with corrosive mercurial sublimate and water, and triturating it with running mercury. Half an hour's trituration is here sufficient; because the water contributes to confound the two substances together. The process ends with digesting the mixture on a sand-bath by a moderate heat; the matter changes its original gray colour for white, and forms a very mild mercurial sublimate, which needs only to be sublimed in order that it may be perfectly pure.

Baumé has made several experiments on mild mercurial sublimate. He has shewn that it cannot receive an additional quantity of mercury; and that it cannot exist in a middle state, between the corrosive and the mild mercurial sublimate. That is to say, where a smaller portion of mercury is mixed with the corrosive mercurial sublimate, than is requisite to make it pass into the state of mild mercurial sublimate, a portion of this latter salt is formed, in proportion to the quantity of the mercury, and the excess of the corrosive sublimate; and the rest of the corrosive mercurial sublimate is volatilized without suffering any alteration of its properties. These two compounds are separable by hot water.

From the researches of the same chemist we learn further, that it is possible to change the mild into corrosive mercurial sublimate, by sublimating it with decrepitated marine salt and white calcined vitriol of iron. In this operation the muriatic acid being disengaged, and aerated by the sulphuric acid, unites with the mercurial calx of the mild mercury, and converts it into corrosive sublimate.

limate. Baume is convinced that mild mercurial sublimate differs greatly from the corrosive, as it cannot unite with sal ammoniac like the corrosive mercurial sublimate in the formation of alembroth salt, or ammoniaco-mercurial muriate. It is even from the consideration of its possessing this property, that he advises to wash mild mercurial sublimate with water impregnated with a little sal ammoniac, to carry off all the corrosive mercurial sublimate which renders that salt so very soluble. Lastly, he has discovered that at each sublimation mild mercurial sublimate loses a part of its mercury, and affords of consequence a certain quantity of corrosive mercurial sublimate; so that by repeated sublimation mild mercurial sublimate may be entirely changed into corrosive. From this last fact it follows, that the medicine known by the name of mercurial panacea, which consists of mild mercurial sublimate nine times sublimed, is so far from being rendered milder by being so often sublimed, as most chemists and physicians think, that at the end of the process it differs in no respect from what it was at first. A circumstance attending the operation may be considered as a farther proof of this assertion; at each sublimation a small quantity of white powder which rises is first taken off, which powder is nothing but corrosive mercurial sublimate. It is to be observed, that there remains in the phials a reddish powder, when mild mercurial sublimate is prepared. It is calx of iron produced from the vitriol of iron, which is employed in preparing the common corrosive mercurial sublimate. Part of that calx ascends with the salt in its sublimation; nay, the mercurial salt in vapour is often found to carry up with it even pieces of glass.

Late experiments on the aerated muriatic acid render the theory of the formation of mild mercurial sublimate much more clear and intelligible than it formerly was. It has been proved that corrosive mercurial sublimate is a compound of aerated muriatic acid with calx of mercury, and that mild mercurial sublimate is formed by the common muriatic acid with the same metallic calx: or, what amounts to the same thing, that in corrosive sublimate the calx is much more calcined than in the sublimate. Thus, when running mercury is triturated with corrosive mercurial sublimate, the mercury seizes the excess of vital air contained in the marine acid, or in the former mercurial calx; and as a larger quantity of mercurial calx, and that less completely calcined, now combines with the same quantity of marine acid, the nature of the salt is of consequence altered, and it becomes less saline, more insipid, and more insoluble: in a word, its qualities are weakened in proportion as the quantity of the mercurial calx is increased.

**SUBLIMATION** is a process by which volatile substances are raised by heat, and again condensed in the solid form.

This operation is founded on the same principles as distillation, and its rules are the same, as it is nothing but a dry distillation. Therefore all that has been said on the article **DISTILLATION** is applicable here, especially in those cases where sublimation is employed to separate volatile substances from others which are fixed or less volatile.

Sublimation is also used in other cases: for instance, to combine volatile matters together, as in the operation of the sublimate of mercury; or to collect some volatile substances, as the acid of borax, sulphur, and all the preparations called flowers.

The apparatus for sublimation is very simple. A matrass or small alembic is generally sufficient for the sublimation of small quantities of matter. But the vessels and the method of managing the fire vary according to the nature of the  
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matters which are to be sublimed, and according to the form which is to be given to the sublimate.

The beauty of some sublimates consists in their being composed of very fine, light parts, such as almost all those called flowers; as flowers of sulphur, of benjamin, and others of this kind. When the matters to be sublimed are at the same time volatile, a high cucurbit, to which is adapted a capital, and even several capitals placed one upon another, are employed. The sublimation is performed in a sand-bath, with only the precise degree of heat requisite to raise the substance which is to be sublimed, and the capitals are to be guarded as much as possible from heat. The height of the cucurbit and of the capitals seems well contrived to accomplish this intention.

When along with the dry matter which is to be collected in these sublimations a certain quantity of some liquor is raised, as happens in the sublimation of acid of borax, and in the rectification of volatile concrete alkali, which is a kind of sublimation, a passage and a receiver for these liquors must be provided. This is conveniently done by using the ordinary capital of the alembic, furnished with a beak and a receiver.

Some sublimates are required to be in masses as solid and compact as their natures allow. Of this number are camphor, sal ammoniac, and all the sublimates of mercury. The properest vessels for these sublimations are bottles or matraffes, which are to be sunk more or less deeply in sand, according to the volatility and gravity of the matters that are to be sublimed. In this manner of subliming, the substances having quitted the bottom of the vessel, adhere to its upper part; and as this part is low and near the fire, they there suffer a degree of heat sufficient to give them a kind of fusion. The art, therefore, of conducting these sublimations, consists in applying such a degree of heat, or in so disposing the sand (that is, making it cover more or less the matraffs), that the heat in the upper part of the matraffs shall be sufficient to make the sublimate adhere to the glass, and to give it such a degree of fusion as is necessary to render it compact; but at the same time this heat must not be so great as to force the sublimate through the neck of the matraffs, and dissipate it. These conditions are not easily to be attained, especially in great works.

Many substances may be reduced into flowers, and sublimed; but which require for this purpose a very great heat, with the access of free air, and even the contact of coals, and therefore cannot be sublimed in close vessels. Such are most roots or flowers of metals, and even some saline substances. When these sublimates are required, the matters from which they are to be separated must be placed among burning coals in open air; and the flowers are collected in the chimney of the furnace in which the operation is performed. The tutty, calamine, or pompholix, collected in the upper part of furnaces in which ores are smelted, are sublimates of this kind.

SUGAR is a constituent part of vegetables, existing in considerable quantities in a number of plants. It is afforded by the maple, the birch, wheat, and Turkey corn. Margraaf obtained it from the roots of beet, red beer, skirret, parsneps, and dried grapes. The process of this chemist consisted in digesting these roots, rasped or finely divided, in alcohol. This fluid dissolves the sugar; and leaves the extractive matter untouched, which falls to the bottom.

In Canada the inhabitants extract sugar from the maple (*acer montanum candidum*). At the commencement of spring they heap snow in the evening at the foot of the tree, in which they previously make apertures for the passage of the  
returning

returning sap. Two hundred pounds of this juice afford by evaporation fifteen of a brownish sugar. The quantity prepared annually amounts to fifteen thousand weight.

Dr. Rush, in the Transactions of the American Philosophical Society, vol. iii. has given an account at length of the sugar maple-tree, of which the following is a short abstract :

The *acer saccharinum* of Linné, or sugar maple-tree, grows in great quantities in the western counties of all the middle states of the American union. It is as tall as the oak, and from two to three feet in diameter; puts forth a white blossom in the spring, before any appearance of leaves: its small branches afford sustenance for cattle, and its ashes afford a large quantity of excellent pot-ash. Twenty years are required for it to attain its full growth. Tapping does not injure it; but on the contrary it affords more syrup, and of a better quality, the oftener it is tapped. A single tree has not only survived, but flourished, after tapping for forty years. Five or six pounds of sugar are usually afforded by the sap of one tree; though there are instances of the quantity exceeding twenty pounds. The sugar is separated from the sap either by freezing, by spontaneous evaporation, or by boiling. The latter method is the most used. Dr. Rush describes the process, which is simple, and practised without any difficulty by the farmers.

From frequent trials of this sugar, it does not appear to be in any respect inferior to that of the West Indies. It is prepared at a time of the year when neither insect, nor the pollen of plants, exists to vitiate it, as is the case with common sugar. From calculations grounded on existing facts, it is ascertained, that America is now capable of producing a surplus of one eighth more than its own consumption; that is, on the whole, about 135,000,000 pounds; which in the country may be valued at fifteen pounds weight for one dollar.

The Indians likewise extract sugar from the pith of the bamboo.

But the sugar which is so universally used is afforded by the sugar-cane (*arundo saccharifera*), which is raised in our colonies. When this plant is ripe, it is cut down, and crushed by passing it between iron cylinders, placed perpendicularly, and moved by water or animal strength. The juice which flows out by this strong pressure is received in a shallow trough placed beneath the cylinder. This juice is called in the French sugar-colonies *vesou*; and the cane, after having undergone this pressure, is called *begasse*. The juice is more or less saccharine, according to the nature of the soil on which the cane has grown, and the weather that has predominated during its growth. It is aqueous when the soil or the weather has been humid; and in contrary circumstances it is thick and glutinous.

The juice of the cane is conveyed into boilers, where it is boiled with wood ashes and lime. It is subjected to the same operation in three several boilers, care being taken to remove the scum as it rises. In this state it is called syrup; and is again boiled with lime and alum till it is sufficiently concentrated, when it is poured into a vessel called the cooler. In this vessel it is agitated with wooden stirrers, which break the crust as it forms on the surface. It is afterwards poured into casks, to accelerate its cooling; and while it is still warm, it is conveyed into barrels standing upright over a cistern, and pierced through their bottom with several holes stopped with cane. The syrup which is not condensed filters through these canes into the cistern beneath; and leaves the sugar in the state called coarse sugar, or *muscovado*. This sugar is yellow and fat, and is purified in the islands in the following manner: The syrup is boiled, and poured into conical earthen vessels,



vessels, having a small perforation at the apex, which is kept closed. Each cone, reversed on its apex, is supported in another earthen vessel. The syrup is stirred together, and then left to crystallize. At the end of fifteen or sixteen hours, the hole in the point of each cone is opened, that the impure syrup may run out. The base of these sugar loaves is then taken out, and white pulverized sugar substituted in its stead; which being well pressed down, the whole is covered with clay, moistened with water. This water filters through the mass, carrying the syrup with it which was mixed with the sugar, but which by this management flows into a pot substituted in the place of the first. This second fluid is called fine syrup. Care is taken to moisten and keep the clay to a proper degree of softness, as it becomes dry. The sugar loaves are afterwards taken out, and dried in a stove for eight or ten days; after which they are pulverized, packed, and exported to Europe, where they are still further purified.

The operation of the French sugar refiners consists in dissolving the cassonade, or clayed sugar, in lime water. Bullocks blood is added, to promote the clarifying; and, when the liquor begins to boil, the heat is diminished, and the scum carefully taken off. It is in the next place concentrated by a brisk heat; and, as it boils up, a small quantity of butter is thrown in, to moderate its agitation. When the boiling is sufficiently effected, the fire is put out; the liquor is poured into moulds, and agitated, to mix the syrup together with the grain sugar already formed. When the whole is cold, the moulds are opened, and the loaves are covered with moistened clay, which is renewed from time to time till the sugar is well cleansed from its syrup. The loaves being then taken out of the moulds, are carried to a stove, where they are gradually heated to the fiftieth degree of Reaumur. They remain in this stove eight days, after which they are wrapped in blue paper for sale.

The several syrups, treated by the same methods, afford sugars of inferior qualities; and the last portion, which no longer affords any crystals, is sold by the name of melasses. The Spaniards use this melasses in the preparation of sweet-meats.

A solution of sugar, much less concentrated than that we have just been speaking of, lets fall by repose crystals which affect the form of tetrahedral prisms, terminated by dihedral summits, and known by the name of sugar-candy.

The preceding account of the manufacture of sugar in the colonies is chiefly extracted from Chaptal. The following more ample account is taken from Edwards's History of the West Indies, the authority of which is indubitable. For the sake of conciseness I have availed myself of the Abridgment lately published, which appears to be faithfully done.

The botanical name of the sugar-cane is *arundo saccharifera*. It is a jointed reed, which terminates in leaves or blades, whose edges are finely and sharply serrated. The body of the cane, though brittle, is strong, and, when ripe, is of a fine straw colour inclinable to yellow. It likewise contains a soft pithy substance, which is replete with juice of a most agreeable taste. The general distance between each joint of the cane, is from one to three inches in length, and from half an inch to an inch in diameter; and the general height, (the flag part being excluded) is from three feet and a half to seven feet. In very rich lands, too, the stool or root has been known to put forth upwards of one hundred suckers or shoots.

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To bring a plant of this rank and succulent nature to perfection, no land can be too rich; and the ashy loam of St. Christopher's appears to be the best soil hitherto known, for the production of sugar of the finest quality, and in the largest proportion. The next to this in excellence is the soil which in Jamaica is called brick-mould. It is a deep, warm, and mellow, hazel earth, which is easily worked, and which in the wettest season seldom requires trenching. In a very fine season, plant-canes (which are those of the first growth) have been known, in this soil, to yield two tons and a half of sugar per acre. The black mould of several varieties may be reckoned after this. The best is the deep black earth of Barbadoes, Antigua, and some other of the windward islands; but there is a species of this mould in Jamaica, that is perhaps not in the least inferior to it, which abounds with lime-stone and flint, on a substratum of soapy marle. Black mould on clay is more common; and, when properly pulverized and manured, becomes very productive, and may be said to be inexhaustible. But there are few soils that produce a greater return of refined sugar, than a peculiar sort of land on the north side of Jamaica, and particularly in the parish of Trelawney. This land is generally of a red colour, is every where remarkable when first turned up for a glossy surface, and, when wetted, stains the fingers like paint. It appears to consist of a native earth or pure loam, with a mixture of clay and sand; and though deep, it is by no means heavy, and is naturally dry. Hence, as its fertility is destroyed when too much exposed to the burning influence of a tropical sun, the system of husbandry, where this soil abounds, chiefly depends on what is called ratoon canes. Ratoons are the suckers that spring from the roots or stoles of the canes that have been previously cut for sugar, and are generally ripe in twelve months. Plant canes, or canes of the first growth, are the immediate produce of the original germs placed in the ground, and require from fifteen to seventeen months to bring them to maturity. The first yearly returns from their roots are called first ratoons, the second year's growth second ratoons, and so on, according to their age. The common yielding too of this cane-land, on an average, is seven hogheads of 16 cwt. to ten acres, which are cut every year.

The crop time in the sugar islands is the season of festivity, both to man and beast; for so agreeable to the taste, and so nourishing to the corporeal frame, is the juice of the cane, that every animal derives health and vigour from its use. Such of the negroes as were meagre and sickly, become surprisingly altered for the better in a few weeks after the mill is set in action. The labouring horses, oxen, and mules, though almost constantly at work during this season, yet, in consequence of eating plentifully of the green tops of this invigorating plant, and being indulged with some of the scummings from the boiling-house, improve more than at any other period of the year. Even pigs and poultry fatten on the refuse. In short, during crop-time, plenty and industrious cheerfulness every where prevail in such a high degree on a well-regulated plantation, as considerably to soften the hardships of slavery, and induce an impartial spectator to conclude, that the miseries of life are sometimes exaggerated through the delusive medium of fancy.

Such planters as are not fortunately furnished with the means of grinding their canes by water, are at this season frequently impeded by the failure or insufficiency of their mills; for though a sugar-mill is a very simple contrivance, yet great force is requisite to make it vanquish the resistance which it necessarily meets with. It principally consists of three upright iron rollers or cylinders, from thirty to forty inches in length, and from twenty to twenty-five inches



in diameter; and the middle one, to which the moving power is applied, turns the other two by means of cogs. The canes, which are previously cut short and tied into bundles, are twice compressed between these rollers; for after they have passed through the first and second rollers, they are turned round the middle one by a piece of frame-work of a circular form, which is called in Jamaica the dumb-returner, and forced back through the second and third. By this operation they are squeezed completely dry, and sometimes even reduced to powder. The cane-juice is received in a leaden-bed, and thence conveyed into a vessel called the receiver. The refuse, or macerated rind of the cane, which is called cane-trash, serves for fuel to boil the liquor.

The juice from the mill usually contains eight parts of pure water, one part of sugar, and one part made up of gross oil, and mucilaginous gum, with a portion of essential oil. The proportions are taken at a medium; for some juice has been so rich as to make a hoghead or sixteen hundred weight of sugar from thirteen hundred gallons, and some is so watery as to require more than double that quantity. The richer the juice is, the less it abounds with redundant oil and gum; so that very little knowledge of the contents of any other quantity can be obtained by the most exact analysis of any one quantity of juice.

The following matters are likewise usually contained in cane-juice. Some of the green tops, which serve to tie the canes in bundles, are often ground in, and yield a raw acid juice exceedingly disposed to ferment and render the whole liquor sour. Besides these they grind in some pieces of the ligneous part of the cane, some dirt, and lastly, a substance of some importance, which may be called the crust. This substance is a thin black coat of matter that surrounds the cane between the joints, beginning at each joint, and gradually growing thinner the farther from the joint upwards, till the upper part between the joints appears entirely free from it, and resumes its bright yellow colour. It is a fine black powder, that mixes with the clammy exudations from the cane; and as the fairness of the sugar is one symptom of its goodness, a small quantity of this crust must very much prejudice the commodity.

The sugar is obtained by the following process: The juice or liquor runs from the receiver to the boiling-house, along a wooden gutter lined with lead. In the boiling-house, it is received into one of the copper pans or cauldrons called clarifiers. Of these there are generally three; and their dimensions are determined by the power of supplying them with liquor. There are water-mills that will grind with great facility sufficient for thirty hogheads of sugar in a week. Methods of quick boiling cannot be dispensed with on plantations thus fortunately provided; for otherwise the cane liquor would unavoidably become tainted before it could be exposed to the fire. The purest cane-juice will not remain twenty minutes in the receiver without fermenting. Hence, clarifiers are sometimes seen of one thousand gallons each. But on plantations that during crop time make from fifteen to twenty hogheads of sugar a week, three clarifiers of three or four hundred gallons each are sufficient. The liquor, when clarified, may be drawn off at once, with pans of this size, and there is leisure to cleanse the vessels every time they are used. Each clarifier is furnished either with a syphon or cock for drawing off the liquor. It has a flat bottom, and is hung to a separate fire, each chimney having an iron slider, which, when shut, causes the fire to be extinguished through want of air.

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\* The clarifiers are generally placed in the middle or at one end of the boiling-house. When they are

As soon as the stream from the receiver has filled the clarifier with fresh liquor, and the fire is lighted, the temper, which is generally Bristol white-lime in powder, is stirred into it. This is done, in order to neutralize the superabundant acid, and to get rid of which is the great difficulty in sugar-making. Alkali, or lime, generally effects this; and at the same time part of it is said to become the basis of the sugar. Mr. Edwards affirms that it affects both the smell and taste of the sugar. It falls to the bottom of the pans in a black insoluble matter, which scorches the bottom of the vessels, and cannot without difficulty be detached from them. But in order that less of the lime may be precipitated to the bottom, little more than half a pint of Bristol lime should be allowed to every hundred gallons of liquor, and Mr. Boussie's method of dissolving it in boiling water previous to mixing it with the cane-juice should be adopted.

As the force of the fire increases, and the liquor grows hot, a scum is thrown up, which is formed of the gummy matter of the cane, with some of the oil, and such impurities as the mucilage is able to entangle. The heat is now suffered to increase gradually till it nearly rises to the heat of boiling water. The liquor, however, must by no means be suffered to boil. When the scum begins to rise into blisters, which break into white froth, and generally appear in about forty minutes, it is known to be sufficiently heated. Then the damper is applied, and the fire extinguished; and if circumstances will admit, the liquor after this is suffered to remain a full hour undisturbed. In the next place, it is carefully drawn off, either by a syphon, which draws up the clear fluid through the scum, or by means of a cock at the bottom. In either case, the scum sinks down without breaking as the liquor flows; for its tenacity prevents any admixture. The liquor is received into a gutter or channel, which conveys it to the evaporating boiler, commonly called the grand copper, and if produced at first from good and untainted canes, it will then appear almost transparent.

In the grand or evaporating copper, which should be sufficiently large to receive the net contents of one of the clarifiers, the liquor is suffered to boil, and the scum, as it rises, is continually taken off by large scummers, till the liquor becomes finer and somewhat thicker. This operation is continued till the subject is so reduced in quantity, that it may be contained in the next or second copper, into which it is then laded. The liquor is now almost of the colour of Madeira wine. In the second copper the boiling and scumming are continued; and if the subject is not so clean as is expected, lime-water is thrown into it. This addition not only serves to give more temper, but likewise to dilute the liquor, which sometimes thickens too fast to permit the feculencies to rise in the scum. When the froth in boiling arises in large bubbles, and is not much dis-

are placed at one end, the boiler called the teache is placed at the other, and three boilers are usually ranged between them. The teache commonly holds from 70 to 100 gallons, and the boilers between the clarifiers and teache diminish in size from the first to the last. But when the clarifiers are in the middle, there is generally a set of three boilers on each side, which in effect form a double boiling-house. This arrangement is very necessary on large estates.

\* Mr. Boussie, to whom, for his improvements in the art of sugar-boiling, the Assembly of Jamaica gave 1,000l., in a paper which he distributed among the members recommends the use of a vegetable alkali, or ashes of wood, such as pimento tree, dumb cane, fern tree, cashew or logwood, as affording a better temper than quick-lime. Afterwards, however, he was convinced that sugar formed on the basis of fixed alkaline salts never stands the sea, unless some earth is united to the salts. Such earth as approaches nearest to the basis of alum, Mr. Edwards thinks, would be most proper; and it deserves to be inquired how far a proper mixture of vegetable alkaline salts and lime might prove a better temper than either lime or alkaline salts alone. In some parts of Jamaica, where the cane-liquor was exceedingly rich, Mr. Boussie made very good sugar without a particle of temper.

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coloured, the liquor is said to have a favourable appearance in the second copper. When in consequence of such scumming and evaporation, the liquor is again so reduced that it may be contained in the third copper, it is laded into it, and so on to the last copper, which is called the teache. This arrangement supposes four boilers or coppers, besides the three clarifiers.

In the teache the subject undergoes another evaporation, till it is supposed boiled enough to be removed from the fire. This operation is usually called striking, i. e. lading the liquor, which is now exceeding thick, into the cooler.

The cooler, of which there are generally six, is a shallow wooden vessel, about eleven inches deep, seven feet in length, and from five to six feet wide. A cooler of this size holds a hoghead of sugar. Here the sugar grains, i. e. as it cools, it runs into a coarse irregular mass of imperfect crystals, separating itself from the melasses. From the cooler it is taken to the curing-house, where the melasses drains from it\*.

But here it may be proper to notice the rule for knowing when the subject is fit to be laded from the teache to the cooler. Many of the negro boilers, from long habit, guess accurately by the eye alone, judging by the appearance of the grain on the back of the ladle; but the practice generally adopted is to judge by what is called the touch, i. e. taking up with the thumb a small portion of the hot liquor from the ladle, and, as the heat diminishes, drawing with the forefinger the liquid into a thread. This thread will suddenly break and shrink from the thumb to the suspended finger, in different lengths, according as the liquor is more or less boiled. A thread of a quarter of an inch long generally determines the proper boiling height for strong muscovado sugar†.

The curing-house is a large airy building, provided with a capacious melasses cistern, the sides of which are sloped and lined with terras, or boards. A frame of massy joist-work without boarding is placed over this cistern; and empty hogheads without headings are ranged on the joists of this frame. Eight or ten holes are bored in the bottoms of these hogheads, and through each of the holes the stalk of a plantain leaf is thrust six or eight inches below the joists, and is long enough to stand upright above the top of the hoghead. Into these hogheads the mass from the cooler is put, which is called potting; and the melasses drains through the spongy stalk, and drops into the cistern, from whence it is occasionally taken for distillation. In the space of three weeks, the sugar becomes tolerably dry and fair. It is then said to be cured, and the process is finished.

Sugar thus obtained is called muscovado, and is the raw material from whence

\* It is necessary to observe in this place, that, in order to obtain a large grained sugar, it must be suffered to cool slowly and gradually. If the coolers are too shallow, the grain is injured in a surprising manner.

† The vessel called the teache probably derived its name from this practice of trying by the touch (tactio). Some years ago, John Proculus Baker, Esq. barrister at law, recommended to the public a method more scientific and certain, in a treatise which he published in 1775, entitled *An Essay on the Art of making Muscovado Sugar*. It is as follows: "Provide a small thin pane of clear crown glass, set in a frame, which I would call a tryer; on this drop two or three drops of the subject, one on the other, and carry your tryer out of the boiling-house into the air. Observe your subject, and more particularly whether it grains freely, and whether a small edge of melasses separates at the bottom. I am well satisfied that a little experience will enable you to judge what appearance the whole skip will put on when cold, by this specimen which is also cold. This method is used by chemists, to try evaporated solutions of all other salts: it may seem therefore somewhat strange, it has not been long adopted in the boiling-house."

the British sugar-bakers chiefly make their loaf or refined lump. There is another sort which was formerly much used in Great-Britain for domestic purposes, and was generally known by the name of Lisbon sugar. In the West-Indies it is called clayed sugar; and the process of making it is as follows:

A quantity of sugar from the cooler is put into conical pots or pans, which the French call formes, with the points downwards, having a hole about half an inch in diameter at the bottom, for the melasses to drain through, but which at first is closed with a plug. As soon as the sugar in these pots is cool, and becomes a fixed body, which is known by the middle of the top falling in, the plug is taken out, and the pot placed over a large jar, intended to receive the syrup or melasses that drains from it. In this state it is left as long as the melasses continues to drop, when a stratum of clay is spread on the sugar, and moistened with water. This imperceptibly oozing through the pores of the clay, dilutes the melasses, in consequence of which more of it comes away than from sugar cured in the hoghead, and the sugar of course becomes so much whiter and purer. According to Sloane, the process was first discovered in Brasil, by accident: "A hen (says he) having her feet dirty, going over a pot of sugar, it was found under her feet to be whiter than elsewhere." The reason assigned why this process is not universally adopted in the British sugar islands, is this, that the water which dilutes and carries away the melasses, dissolves and carries with it so much of the sugar, that the difference in quality does not pay for the difference in quantity. It is probable however, that the French planters are of a different opinion; for upwards of four hundred of the plantations of St. Domingo have the necessary apparatus for claying, and actually carry on the system.

Sugar is very soluble in water, and is a good medium for uniting that fluid with oily matters. It is much used for domestic purposes, and appears upon the whole to be a valuable and wholesome article of food, the uses of which are most probably restricted by its high price. This price may in a certain degree arise from the nature of the article and its original cost; but is no doubt in a great measure owing to the inhuman and wasteful culture by slaves, and the absurd principles of European colonization, duties, draw-backs, and bounties, which have the effect to create unnatural monopolies, and to prevent commerce from finding its level. This is eminently the case with regard to our West-India islands, and their produce.

One very extensive use of sugar and saccharine juices consists in the formation of ardent spirit, an article which, all things considered, is perhaps a curse to society. The wines or beers of pure sugar ferment so rapidly, that they can scarcely be kept, but are for the most part made for immediate use. I do not know of any beer of pure sugar, which is stored and kept for sale. See SPIRIT ARDENT, BEER, WINE.

Modern chemists have made various experimental enquiries with this substance, for which see ACID OF SUGAR, and ACID OF SUGAR EMPYREUMATIC.

SUGAR OF LEAD. See LEAD.

SUGAR OF MILK. See MILK.

SULPHUR, or brimstone, is a well known, hard, brittle, inflammable substance, of an opaque yellow colour. It is found more or less pure in the neighbourhood of volcanos; where most probably it is always expelled from some previous state of combination, by the heat of subterraneous fires. It is a very common ingredient in a great variety of minerals and ores; but it is extracted for sale chiefly from a stone called pyrites.



In order to obtain sulphur from pyrites, this mineral ought to be exposed to a heat sufficient to sublime the sulphur, or to make it distil in vessels, which must be close to prevent its burning.

Sulphur is extracted from pyrites at a work at Schwartzemberg, in Saxony, in the high country of the mines, and in Bohemia, at a place called Alten-Sattel.

The furnaces employed for this operation are described by Macquer. They are oblong, like vaulted galleries; and in the vaulted roofs are made several openings. These are called furnaces for extracting sulphur.

In these furnaces are placed earthen ware tubes, filled with pyrites broken into pieces, of the size of small nuts. Each of these tubes contains about fifty pounds of pyrites. They are placed in the furnace almost horizontally, and have scarcely more than an inch of descent. The ends, which come out of the furnace five or six inches, become gradually narrower. Within each tube is fixed a piece of baked earth, in form of a star, at the place where it begins to become narrower, in order to prevent the pyrites from falling out, or choking the mouth of the tube. To each tube is fitted a receiver, covered with a leaden plate, pierced with a small hole to give air to the sulphur. The other end of the tube is exactly closed. A moderate fire is made with wood, and in eight hours the sulphur of the pyrites is found to have passed into the receivers.

The residuum of the pyrites, after the distillation, is drawn out at the large end, and fresh pyrites is put in its place. From this residuum, which is called burnings of sulphur, vitriol is extracted. See ACID VITRIOLIC.

The eleven tubes into which are put, at three several distillations, in all nine quintals, or 900 pounds of pyrites, yield from 100 to 150 pounds of crude sulphur, which is so impure as to require to be purified by a second distillation.

This purification of crude sulphur is also done in a furnace in form of a gallery, in which five iron cucurbits are arranged on each side. These cucurbits are placed in a sloping direction, and contain about eight quintals and a half of crude sulphur. To them are luted earthen tubes, so disposed as to answer the purpose of capitals. The nose of each of these tubes is inserted into an earthen pot, called the forerunner. This pot has three openings; namely, that which receives the nose of the tube; a second smaller hole, which is left open to give air; and a third in its lower part, which is stopped with a wooden peg.

When the preparations are made, a fire is lighted about seven o'clock in the evening, and is a little abated as soon as the sulphur begins to distil. At three o'clock in the morning, the wooden pegs, which stop the lower holes of the forerunners, are for the first time drawn out, and the sulphur flows out of each of them into an earthen pot with two handles placed below for its reception. In this distillation the fire must be moderated and prudently conducted; otherwise less sulphur would be obtained, and it would also be of a gray colour, and not of the fine yellow which it ought to have when pure. The ordinary loss in the purification of eight quintals of crude sulphur is, at most, one quintal.

When all the sulphur has flowed out, and has cooled a little in the earthen pots, it is cast into moulds made of beech-tree, which have been previously dipped in water, and set to drain. As soon as the sulphur is cooled in the moulds, they are opened, and the cylinders of sulphur are taken out and put up in casks. These are called roll brimstone.

As sulphur exists not only in pyrites, but also in most metallic minerals, it is evident

evident that it might be obtained by works in the large way from the different ores which contain much of it, and from which it must be separated previously to their fusion : but as sulphur is of little value, the trouble of collecting it from ores is seldom taken. Smelters are generally satisfied with freeing their ores from it, by exposing them to a fire sufficient to expel it. This operation is called torrefaction, or roasting of ores. See ORES.

There are, however, ores which contain so much sulphur, that part of it is actually collected in the ordinary operation of roasting, without much trouble for that purpose. Such is the ore of Ramelsberg, in the county of Hartz.

This ore, which is of lead containing silver, is partly very pure, and partly mixed with cupreous pyrites and sulphur ; hence it is necessary to roast it.

The roasting is performed by laying alternate strata of ore and wood upon each other in an open field, taking care to diminish the size of the strata as they rise higher, so that the whole mass shall be a quadrangular pyramid truncated above, whose base is about thirty-one feet square. Below, some passages are left open, to give free entrance to the air ; and the sides and top of the pyramid are covered over with small ore, to concentrate the heat and make it last longer. In the centre of this pyramid there is a channel, which descends vertically from the top to the base. When all is properly arranged, ladle-fulls of red hot scoria from the smelting furnace are thrown down the channel, by which means the shrubs and wood, placed below for that purpose, are kindled, and the fire is from them communicated to all the wood of the pile, which continues burning till the third day. At that time the sulphur of the mineral becomes capable of burning spontaneously, and of continuing the fire after the wood is consumed.

When this roasting has been continued fifteen days, the mineral becomes greasy, that is, it is covered over with a kind of varnish : twenty or twenty-five holes or hollows are then made in the upper part of the pile, in which the sulphur is collected. From these cavities the sulphur is taken out thrice every day, and thrown into water. This sulphur is not pure, but crude, and is therefore sent to the manufacturers of sulphur to be purified in the manner above related.

As this ore of Ramelsberg is very sulphureous, the first roasting, which we are now describing, lasts three months ; and during this time if much rain has not fallen, or if the operation has not failed by the pile falling down or cracking, by which the air has so much free access that the sulphur is burnt and consumed, from ten to twenty quintals of crude sulphur are by this method collected.

The sulphur of this ore, like that of most others, was formerly neglected, till in the year 1570 a person employed in the mines, called Christopher Sauder, discovered the method of collecting it, nearly as it is done at present.

Metallic minerals are not the only substances from which sulphur is extracted ; this matter is diffused in the earth in such quantities, that the metals cannot absorb it all. Some sulphur is found quite pure, and in different forms, principally in the neighbourhood of volcanos, in caverns, and in mineral waters. Such are the opaque kind, called virgin sulphur ; the transparent kind, called sulphur of quito ; and the native flowers of sulphur, as those of the waters of Aix-la-Chapelle. It is also found mixed with different earths. Here we may observe, that all those kinds of sulphur which are not mineralized by metallic substances, are found near volcanos, or hot mineral waters, and consequently in places where nature seems to have formed great subterranean laboratories, in which sulphureous minerals may be analyzed and decomposed, and the sulphur separated in the manner in which it is done in the small way in our works and laboratories. However that may be, certainly one of the best and most famous sulphur mines in the world



is that called Solfatara. The Abbé Nollet has published, in the Memoirs of the Academy, some interesting observations upon this subject, of which Macquer gives the following abridgment:

Near Puzzoli, in Italy, is that great and famous mine of sulphur and ahim, called at present Solfatara. It is a small oval plain, the greatest diameter of which is about 400 yards, raised about 300 yards above the level of the sea. It is surrounded by high hills and great rocks, which fall to pieces, and whose fragments form very steep banks. Almost all the ground is bare and white, like marle; and is every where sensibly warmer than the atmosphere in the greatest heat of summer; so that the feet of persons walking there are burnt through their shoes. It is impossible not to observe the sulphur there; for every where may be perceived by the smell a sulphureous vapour, which rises to a considerable height, and gives reason to believe that there is a subterraneous fire below, from which that vapour proceeds.

Near the middle of this field there is a kind of bason three or four feet lower than the rest of the plain, in which a sound may be perceived when a person walks on it, as if there were under his feet some great cavity, the roof of which was very thin. After that, the lake Agnano is perceived, whose waters seem to boil. These waters are indeed hot, but not so hot as boiling water. This kind of ebullition proceeds from vapours which rise from the bottom of the lake, which being set in motion by the action of subterranean fires, have force enough to raise all that mass of water. Near this lake there are pits, not very deep, from which sulphureous vapours are exhaled. Persons who have the itch come to these pits, and receive the vapours in order to be cured. Finally, there are some deeper excavations, whence a soft stone is procured which yields sulphur. From these cavities vapours exhale, and issue out with noise, and which are nothing else than sulphur subliming through the crevices. This sulphur adheres to the sides of the rocks, where it forms enormous masses: in calm weather the vapours may be evidently seen to rise twenty-five or thirty feet from the surface of the earth.

These vapours, attaching themselves to the sides of rocks, form enormous groups of sulphur, which sometimes fall down by their own weight, and render these places of dangerous access.

In entering the Solfatara, there are warehouses and buildings erected for the refining of sulphur.

Under a great shed, or hangar, supported by a wall behind, open on the other three sides, the sulphur is procured by distillation from the soft stones we mentioned above. These stones are dug from under ground; and those which lie on the surface of the earth are neglected. These last are, however, covered with a sulphur ready formed, and of a yellow colour; but the workmen say they have lost their strength, and that the sulphur obtained from them is not of so good a quality as the sulphur obtained from the stones which are dug out of the ground.

These last-mentioned stones are broken in lumps, and put into pots of earthen ware, containing each about twenty pints, Paris measure. The mouths of these pots are as wide as their bottoms; but their bellies, or middle parts, are wider. They are covered with a lid of the same earth, well luted, and are arranged in two parallel lines along two brick walls, which form the two sides of a furnace. The pots are placed within these walls; so that the centre of each pot is in the centre of the thickness of the wall, and that one end of the pots overhangs the wall within, while the other end overhangs the wall without. In each furnace ten of these pots are placed; that is, five in each of the two walls which form

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the two sides of the furnace. Betwixt these walls there is a space of fifteen or eighteen inches; which space is covered by a vault resting on the two walls. The whole forms a furnace seven feet long, two feet and a half high, open at one end, and shut at the other, excepting a small chimney, through which the smoke passes.

Each of these pots has a mouth in its upper part without the furnace, in order to admit a tube of eighteen lines in diameter, and a foot in length, which communicates with another pot of the same size placed without the building, and pierced with a round hole in its base of fifteen or eighteen lines diameter. Lastly, to each of these last-mentioned pots there is a wooden tub placed below, on a bench made for that purpose.

Four or five of these furnaces are built under one hangar or shed. Fires are kindled in each of them at the same time; and they are thrown down after each distillation, either that the pots may be renewed, or that the residuums may be more easily taken out.

The fire being kindled in the furnace, heats the first pots containing the sulphureous stones. The sulphur rises in fumes into the upper part of the pot, whence it passes through the pipe of communication into the external vessel. There the vapours are condensed, become liquid, and flow through the hole below into the tub, from which the sulphur is easily turned out, because the form of the vessel is that of a truncated cone, whose narrower end is placed below; and because the hoops of the tub are so fastened, that they may be occasionally loosened. The mass of sulphur is then carried to the buildings mentioned before, where it is remelted for its purification, and cast into rolls, such as we receive it.

For accurate purposes, sublimation is necessary to deprive sulphur of the accidental impurities it may contain. This may be done in an earthen cucurbit set on a sand bath, with a head properly adapted. The sulphur rises by a very gentle heat, little more than is sufficient to melt it; and the fine sublimate thus obtained is called flowers of brimstone.

Water has no immediate action on sulphur. It is said, however, to soften the outside by long contact with it; and if sulphur be heated nearly to such a degree as to set it on fire, and then poured into water, it becomes soft, and partly transparent. In process of time it recovers its original hardness and opacity. If steam of water be passed over sulphur contained in a heated earthen tube, inflammable air is extricated either from the sulphur or the water, and comes out at the end of the tube\*. The experiment is troublesome, on account of the sulphur subliming.

The combinations of sulphur with earths or alkalis are called hepars, or livers of sulphur, from their colour. There is no perceptible action between sulphur and siliceous earth. Argillaceous earth has very little action upon it in the direct way; but lime unites readily with it. If fresh quick-lime and flowers of sulphur be mixed, and water be added a little at a time, the heat of the lime will be sufficient to produce the combination. On addition of more water it becomes reddish, and emits a fetid smell of rotten eggs, which is common to all the hepars. The more caustic the lime, the deeper the colour of the hepar. The pure fixed alkalis decompose calcareous hepar, by virtue of their stronger affinity to the sulphur; and any acid whatever decomposes it, by attracting the lime, the sulphur at the same time falling to the bottom in the form of a subtle powder, formerly called magistery of sulphur.

Pure ponderous earth boiled in water with sulphur has but little action upon



it: but in the dry way, when ponderous spar, or the combination of vitriolic acid and ponderous earth, is strongly heated in a crucible with charcoal, a coherent mass is formed, which is soluble in water, with the smell and other hepatic characters; and if any acid be added which will form a soluble salt with the ponderous earth, a precipitate of sulphur will be obtained.

If a small quantity of magnesia, and an equal quantity of flowers of sulphur, be inclosed in a vessel perfectly filled up with distilled water, and well stopped, and then exposed to heat by immersion in boiling water for several hours, a combination will take place; and the water will contain a magnesian liver of sulphur, from which the earth may be precipitated by the addition of an alkali, which will unite with the sulphur: or the sulphur may be precipitated by an acid, which will combine with the earth.

The fixed alkalis combine very readily with sulphur, either in the moist or dry way, whether they be in a pure or caustic state, or combined with fixed air; though more strongly in the former than the latter case. If a solution of fixed alkali in water be boiled with half its weight of powdered sulphur, a combination takes place, and liver of sulphur is formed. Or if equal parts of dry alkali and powdered sulphur be melted in a crucible, and poured out on a flat polished stone, as soon as the fusion is complete the combination will be of a liver colour, and is the solid hepar. If it be made with a pure or caustic alkali, its colour is deeper, and its characteristic properties more intense, than when a mild alkali is used. A solution of the solid hepar in water forms precisely the same substance as the preparation made in the moist way.

The peculiar fetid smell of the solid hepar when moistened, or of its solution, is produced by the emission of a permanently elastic fluid, called hepatic air. This smell when strong is insupportable, and suddenly destroys animal life. Hepatic air is very soluble in water, which it converts into a state perfectly resembling that of the sulphureous mineral springs. It renders syrup of violets green, blackens the calces of lead and bismuth, and the surface of silver. Vital air decomposes it, and causes sulphur to be deposited. It detonates with vital air when set on fire. It is not clearly ascertained in what manner the sulphur is suspended in hepatic air. Sulphur melted by the burning glass in inflammable air over mercury, produces a fluid which has the properties of hepatic air. See LIVER OF SULPHUR, AIR HEPATIC.

The acidification of sulphur by burning has been mentioned and explained under the article ACID VITRIOLIC. The process of combustion is said to be performed in some manufactories in very large glass globes. But the most usual method in England is, as I am informed, by chambers lined with lead. Of these the annotator on Macquer's Dictionary gives the following account. It is said that the process was brought forward in England by the celebrated Dr. Ward.

The greatest part of the vitriolic acid now employed is obtained by burning sulphur. The vapours of burning sulphur are the volatile vitriolic, or sulphureous acid. These are very difficultly condensable. For which reason very large vessels and much time are required in this operation. In great works leaden vessels are used, called houses, of a prismatic form, of which the altitude is about ten feet, and the base, which is a rectangle, is six feet long and four feet broad. The bottom of each of these vessels is covered with a little water to assist the condensation of the vapour. Above the water is placed a small vessel capable of containing a few pounds of sulphur, to which a small portion of nitre is added; because by this addition a larger quantity of sulphur may be burnt without access of fresh air. The vessels are to be filled with the vapour of hot water, and their sides wetted with

with the condensed steam; then the sulphur is to be kindled by touching it with a red-hot iron: the vapour of the burning sulphur rises slowly; and when it has risen as high as the mouth of the great vessel, this must be stopped, or very nearly stopped, that the vapour may be confined. The sulphur continues to burn till the air contained within the vessel and the nitre be no longer capable of maintaining the combustion. The vapour remains a considerable time before it be entirely condensed, notwithstanding that this condensation is facilitated by the water in the vessel, and especially by the steam of water with which the vessel was previously filled. When all the vapour of the sulphureous acid is at last condensed, the sulphur is to be again kindled, and more added if it be necessary, and the process repeated as before. When a sufficient quantity of acid is collected, it is to be taken out of the vessel; and after it has lost its sulphureous or volatile quality by exposure to air, it is concentrated and rectified by distillation.

Mr. Delametherie, in one of his preliminary discourses to the *Journal de Physique*, to which I am not at present able to refer, asserts that the English manufacturers contrive to burn sulphur and condense the product into vitriolic acid, without making use of nitre. The most effective expedient is said to consist in passing the elastic product through a body of water. But Mr. Chaptal, whose knowledge and skill in chemistry, as well as the extensive opportunities he possesses of making experiments in the large way, entitle him to the utmost respect, has in the second volume of the *Annales de Chimie* given an account of some phenomena attending the combustion of sulphur, which shew that some very considerable difficulties attend this process.

When sulphur is burned in a fire constructed on the outside of a chamber of lead, and the current of fumes and smoke is directed into the chamber, the product according to the management will be either sublimed sulphur, soft sulphur, sulphureous acid, or the perfect vitriolic acid.

When the current of air is rapid, and the combustion speedy, a quantity of sulphur is carried into the chamber, and deposited without any perceptible alteration.

If the current of air be moderated, the combination between the sulphur and vital air becomes somewhat more exact; the sulphur is partly acidified, and is deposited in a pellicle on the surface of the water. This pellicle is flexible like a skin, and may be turned and handled in the same manner. Chaptal was frequently obliged to take it out with a cake at its early deposition, when it resembles spider's webs.

If the current of air be still less rapid, and its vital part be allowed the time necessary to combine still more effectually with the sulphur, the product is the sulphureous vitriolic acid, which preserves its elastic form in the temperature of the atmosphere, provided water be not present, but may be condensed by extreme cold, as Monge has shewn. It is the vitriolic acid air.

If the combustion be yet more checked, and, as Chaptal expresses it, if the air be suffered to digest upon the inflamed sulphur, the result is vitriolic acid. This last combination may be facilitated by the mixture of saltpetre, which abundantly furnishes vital air in the dense state.

The addition of saltpetre to the sulphur adds very considerably to the price of the oil of vitriol of commerce. Chaptal affirms that he has made a prodigious number of variations in the manner of burning sulphur for the purpose of diminishing the proportion of this salt. The results of these experiments are as follow:

In 1785 a square chamber lined with lead was prepared for this purpose. Its dimensions were thirty feet (*de trente pieds de dimension*), by which I take it for



for granted the author means a cube measuring thirty feet in its side. He at first adapted to one of the angles a kind of reverberatory furnace, of which the fire-place was two feet in diameter, and the chimney was directed into the chamber. He was astonished at the facility with which sulphur was burned in this furnace. The combustion was kept up by a proper supply for seven successive days, at the end of which time a smell so strong was emitted round the chamber, that the workmen could no longer proceed. This smell was so penetrating that it excited tears, and sneezing of such a convulsive kind as to force blood from the nose. The fire was therefore discontinued, and three or four days afterwards the door of the chamber was opened; whence a gas escaped so subtle and penetrating, that its effect on the skin of the face produced a sensation resembling that of small pins darted into the flesh. As soon as it was practicable to visit the interior part, the water was found to be covered by a membrane of considerable thickness, and sufficiently tenacious to admit of its being drawn about upon the surface of the liquid. This membrane was covered with a stratum of flowers of sulphur. The water marked o on the aerometer of Baumé, and was scarcely acidulated, whereas the eleven quintals and thirty-five pounds of sulphur which had been burned ought to have raised the water to the density of nine degrees, according to former observations, if the vitriolic acid had been produced. This experiment, varied and repeated several times in a small chamber of fifteen by twenty feet square, constantly afforded the same results.

It was therefore requisite to moderate the current of air, that a greater portion of vital air might combine with the sulphur. This was expected to be accomplished by making the aperture of communication between the furnace and the chamber a square of four feet, and admitting the external air to the furnace through a small door furnished with a register. The combustion was neither so easily effected nor so rapid as before; but the detestable smell which issued from the internal part of the chamber rendered it necessary to suspend the combustion for several days together. An issue was likewise given to the vapours several times, by opening the door, and leaving it open for a long time. At length with these precautions twenty-nine quintals were burned in the space of thirty-three days; and when this chemist examined the state of the water, he was not a little surprised to find that it marked only one degree, and scarcely effervesced with alkalis. There was no pellicle on the water, nor sulphur sublimed, which shews in his opinion that the sulphur was converted perfectly enough into sulphureous acid. Whence it should seem that the failure of the experiment must have arisen chiefly from a defect as to the means of condensation.

It obviously appears that these means must consist in increasing the surfaces of contact of the water and sulphureous acid. This may be done by mechanical agitation, by passing the elastic fluid through the water, or by introducing the water in the form of steam. The two latter expedients are said to be used in the English works. I do not find that they occurred to Chaptal at the time of making his experiments. From the unsuccessful issue of this last experiment he renounced the hope of obtaining vitriolic acid by the vital air of the atmosphere alone applied to sulphur, and was more than ever convinced of the necessity of the mixture of saltpetre.

The first effect of the combustion of this mixture is a white thick ponderous vapour, strongly acid, which is easily precipitated and fixed; whence the external air is strongly drawn in to assist the combustion. This vapour is highly phosphoric, as may be seen by inspecting a chamber of lead at the moment when it is filled with these vapours.

As soon as all the vapour is deposited on the water, or on the sides, there remains a sulphureous acid gas, elastic, transparent, and penetrating, which escapes from the internal part of the chamber as soon as the door is opened, and is an impediment to the combustion. This gas is more abundant, the less the proportion of saltpetre in the mixture.

When the door of one of these leaden chambers is opened, a red vapour is seen to come forth, which consists of nitrous air in the act of combination with the vital air of the atmosphere. It is formed in proportion as the external air penetrates into the chamber.

The nitrous acid thus precipitated corrodes the lead and speedily covers its surface with a white calx, which may be employed for the same purposes as ceruse.

**SUMACH** \*. Common sumach (*rhus coriaria*) is a shrub that grows naturally in Syria, Palestine, Spain, and Portugal; in the two last it is cultivated with great care: its shoots are cut down every year quite to the root; and, after being dried, they are reduced to powder by a mill, and thus prepared for the purposes of dyeing and tanning. The sumach cultivated in the neighbourhood of Montpellier is called *rédoul* or *roudou*.

The infusion of sumach, which is of a greenish fawn colour, soon becomes brown by exposure to the air: a solution of pot-ash produces but little change on it while recent; acids brighten its colour, and turn it yellow; solution of alum renders it turbid, and produces in it a small quantity of yellow precipitate; the liquor remains yellow.

Sugar of lead produced immediately a considerable quantity of yellowish precipitate, the surface of which was brown; the liquor remained of a clear yellow.

Vitriol of copper produced a copious precipitate of a yellowish green, which after some hours changed to a brownish green; the liquor remained clear and slightly yellow.

Common vitriol of zinc rendered the liquor turbid, darkened its colour, and produced a deep blue precipitate.

Pure vitriol of zinc did not deepen the colour nearly so much; only a small quantity of a brownish fawn-coloured precipitate was produced.

Sea salt at first produced no sensible change; but after some hours, the liquor became somewhat turbid, and its colour was rendered a little more clear.

Sumach acts on a solution of silver just as galls do; it reduces the silver to its metallic state, and the reduction is favoured by the action of light.

Of all astringents, sumach bears the greatest resemblance to galls: the precipitate, however, produced in solutions of iron by an infusion of it, is less in quantity than what is obtained by an equal weight of galls; so that in most cases it may be substituted for galls, the price of which is considerable, provided we proportionally increase its quantity.

Sumach alone gives a fawn colour inclining to green; but cotton stuffs which have been impregnated with printer's mordant, that is, acetous alum, take a pretty good and very durable yellow. An inconvenience is experienced in employing sumach in this way, which arises from the fixed nature of its colour; the ground of the stuff does not lose its colour by exposure on the grass, so that it becomes necessary to impregnate all the stuff with different mordants to vary the colours, without leaving any part of it white.

\* From Berthollet.



## T

## T A L

## T A M

**TALC.** Pure magnesia, intimately mixed with nearly twice its weight of filex, and less than its own weight of clay, produces Venetian talc.

Its colour is white, gray, yellowish, or greenish; it is soft and soapy to the touch, and in thin pieces semi-transparent; it is composed of very thin laminæ disposed in a laminar or filamentous form, much tenderer and more brittle than those of mica, but like this it has a metallic lustre; its hardness is so inconsiderable that it may be scratched with the nail; and its specific gravity is 2,729.

It does not effervesce with acids; and is soluble therein very difficultly, by particular management, and only in part.

In fire it becomes more brittle and whiter, but is infusible per se by the blow-pipe, and scarcely fusible by fixed alkalis, but more completely and with little effervescence by borax or microcosmic salt.

This talc contains something less than fifty per cent. of filex, and about two per cent. of iron. The magnesia is in smaller quantity, but it exceeds the clay: the exact proportion was not found by Kirwan.

Muscovy talc consists of broad, elastic, flexible, transparent leaves; and differs externally from mica only in being softer and more soapy to the touch. Kirwan.

**TALLOW.** I do not know of any experiments which ascertain a chemical difference between this concrete animal fat, which is chiefly taken from the intestines of animals, and other fat oils of the same nature. The most valuable property of tallow is the considerable heat it requires to fuse it, which is commonly distinguished by the term hardness. The quantity of foot and fetid exhalation emitted from the various kinds of tallow candles brought to market, also form a distinguishing characteristic in the use of this article, and are accompanied with notable variations in the quantities of light afforded by each. It is an object of no small importance to purify or improve tallow. The tallow-chandlers clear it of fibrous matter and other gross impurities by careful melting, straining, and the like mechanical management. It is said also that they improve its whiteness by the addition of alum, the efficacy of which I am much disposed to doubt. It is thought also that long keeping, and the action of the external air, improve its hardness; but these slow operations are ill calculated for a manufactory in which the greatest part of the capital is vested in the raw material and duty, and very little in the manufacturing process.

The aerated marine acid produces a state in tallow which is somewhat nearer to that of wax than before, and a thin stratum of tallow exposed upon an extended surface of water becomes likewise harder; but the indications these processes might afford to the manufacturer have not yet been applied to any extended purposes of utility.

**TALLOW, MINERAL.** See MUMIA.

**TAMARINDS.** *Tamarindi fructus*: *Tamarindi indicæ*, Linn. The fruit of a tree growing in the East and West Indies, called by C. Bauhin *siliqua Arabica quæ tamarindus*. It is a pod resembling a bean-cod, including several hard seeds, together with a dark-coloured viscid pulp of a pleasant acid taste: the East India tamarinds

tamarinds are longer than the West India sort; the former containing six or seven seeds each, the latter rarely above three or four.

**TANNING.** The several kinds of leather are prepared from the skins of animals macerated for a long time with lime and water, to promote the separation of the hair and wool, and of the fat and fleshy parts, in which recourse is also had to the assistance of mechanical pressure, scraping, and the like. The skin, when thus deprived of its more putrescible part, and brought considerably towards the state of mere fibre, is tanned by maceration with certain astringent substances, particularly the bark of the oak-tree. Neumann affirms, that prepared leather, as well as skins, affords a large quantity of glue by boiling in water. The Chevalier de St. Real, in a memoir inserted among those of the Royal Academy of Sciences at Turin, for the years 1788 and 1789, of which an extract by Berthollet is given in the xth volume of the *Annales de Chimie*, p. 44, gives a number of interesting experiments respecting the tanning of skins, to the following effect.

After having exhausted the skin by infusion and a subsequent strong boiling with water, and separating the products obtained by this means, the author has observed, that the skin then consists of nothing but the mere fibres. In the next place he examined the state of tanned leather by the same means. It afforded neither lymph nor jelly, but merely an astringent extract which gave a black precipitate when applied to a solution of iron. The astringent principle of tanned leather could not be exhausted by long boiling with water, for it at last became black when moistened with a solution of martial vitriol.

The author shews, that all the operations performed upon skins preliminary to tanning them, consist in separating such matters as are of a different nature from the epidermes and the fibres which constitute the skin, in order that the astringent principle may afterwards be combined with these animal fibres. He afterwards examines the different processes of the art of tanning, analyses their advantages and imperfections, and has succeeded in simplifying and abridging them, and by that means accelerating the return of capital, of which the investment constitutes a large part of the price of leather. With this view, his enquiries were directed to ascertain what degree of heat is sufficient to extract the animal jelly, and also at what temperature the fibrous texture of the skin begins to suffer alteration. He ascertained that the heat proper to dissolve the animal jelly commences at 48° of Reaumur, which corresponds with 140° of Fahrenheit; and that the fibrous texture is capable of sustaining a degree of heat beyond 60° of Reaumur or 167° of Fahrenheit, without undergoing any alteration in places where the mean temperature of the barometer is 26 inches and 4 lines, I suppose French measure. See MEASURE.

In consequence of his researches and observations, the author proposes to reduce the practice of the art of tanning to the following particulars:

1. The skins are to be kept separately immersed in running water, for a time sufficient to extract the lymph or serum. This period is easily ascertained, by putting a piece of the skin into a small quantity of water, and gradually heating it. If it contain serum, this matter will be first extracted, and afterwards coagulated in the form of scum on the surface. If therefore no scum appear, the skins may be considered as purified from lymphatic matter.

2. These washed and rinsed skins are then to be transferred into boilers properly adapted for the purpose; water is then to be added, and heat applied, so that



the temperature of the water may not exceed 60°. The skins are to remain in this situation for an hour.

3. The skins are then to be taken out, and worked in the usual manner, to clear them of their impurities.

4. After this process they are again to be placed in the boiler, which must be so disposed, that a constant stream of water at the temperature of 60° of Reaumur shall enter by one cock, and pass off by another on the opposite side beneath.

5. The skins are to remain in this situation until the water that comes off exhibits no vestige of animal jelly. This is easily ascertained by evaporating a small quantity.

6. The skins are then to be taken out, and cleared in the usual manner of the cellular membrane, and fleshy parts.

7. Lastly, they are to be washed in a running stream, and replaced in a boiler, similar to that just mentioned, which is to be filled with the filtered juice of tan, or oak bark. The same degree of heat is to be applied, as in the preceding operation, and the skins are to remain until they are perfectly tanned. New juice of tan must be substituted from time to time in the room of that which is exhausted. The exhausted state is shewn by its not having power to afford a black, when a few drops of solution of martial vitriol are added.

The operations which are chiefly practised for strong leather, constitute the first part of M. de St. Real's memoir; his second part is employed on the currying, which is performed upon the soft or flexible leathers.

This leather is most commonly made of calf's skin. It is not exposed for so long a time to the action of the tan as the strong leather. The intention of the art of the currier is to supple the leather, and to render it uniformly compact and dense. The most remarkable defect in the ordinary preparations is, that the leather is more or less penetrable by water. This defect is more especially observable in the leather commonly used for the soles of women's shoes, and may evidently be of great prejudice to the health of the wearer. The author proposes, besides the common operations of currying, that the skin should be impregnated with tallow, by keeping them for a certain time in a bath of this melted substance, and afterwards passing them between rollers. Experience convinced him, that after these two operations, which add but little to the price of the leather, it much more effectually resists the action of water, without having suffered any diminution of strength.

TAR. If the wood of the turpentine trees be exposed to the fire, in a vessel every where closed except an aperture at the bottom, as for example in a retort with the neck placed lowermost, the resinous juice melts out by the heat, and at the same time contracts an empyreumatic smell and taste: in this state it is tar. Tar is prepared in different parts of Germany, Norway, Sweden, &c. from the pine and the fir-trees, and in some places from the larch and the terebinth. The wood is inclosed in a large oven, to the quantity of ten or more loads at a time: this stands within another oven called the mantle, the space betwixt them receiving the fire: from the bottom of the inner oven runs a gutter, by which the tar is conveyed off in proportion as it melts out from the wood.

The above account is from Neumann. Chaptal informs us, that tar is obtained from the wood of the trunk, branches and roots of the pine, which are heaped together, covered with turf, and set on fire to produce a close combustion

tion in the same manner as for making charcoal. The oily parts which are disengaged trickle down, and are received in a gutter which serves to convey them to a tub. The most fluid part is sold under the name of huile de Cade; and the thicker part is the tar used for paying or painting the parts of shipping and other vessels.

**TARRAS, or TERRAS.** A volcanic earth used as a cement. It does not differ much in its principles from pouzzolana. Kirwan gives the following account of them:

The pouzzolana is of a gray, brown, yellowish, or blackish colour, loose, granular, or dusty, and rough, porous, and spongy, resembling a clay hardened in fire, and then reduced to a gross powder. It contains mixed with it various heterogeneous substances: its specific gravity is from 2.5 to 2.8, and it is in some degree magnetic: it scarcely effervesces with acids, though partially soluble in them: it melts easily per se; but its most distinguishing property is, that it hardens very suddenly when mixed with one-third of its weight of lime and water, and forms a cement which is more durable in water than any other. According to Bergman's analysis, 100 parts of it contain from 55 to 60 of siliceous earth, 19 or 20 of argillaceous, 5 or 6 of calcareous, and from 15 to 20 of iron. (3 Berg. 193). It is evidently a martial argillaceous marl that has suffered a moderate heat. Its hardening power arises from the dry state of the half-baked argillaceous particles, which makes them imbibe water very rapidly, and thus accelerates the desiccation of the calcareous part; and also from the quantity and semiphlogisticated state of the iron contained in it. It is found not only in Italy, but also in France, in the provinces of Auvergne and Limoges, and also in England and elsewhere.

Tarras or terras is much more compact, hard, porous, and spongy than pouzzolana. It is generally of a whitish-yellow colour, and contains more heterogeneous particles, as spar, quartz, shoerl, &c. and something more of a calcareous earth. It effervesces with acids, is magnetic, and fusible per se. When pulverized, it serves as a cement, like pouzzolana. It is found in Germany and Sweden.

**TARTAR** is deposited on the sides of casks during the fermentation of wine: it forms a lining more or less thick, which is scraped off. This is called crude tartar, and is sold in Languedoc from ten to fifteen livres the quintal.

All wines do not afford the same quantity of tartar. Neumann remarked, that the Hungarian wines left only a thin stratum; that the wines of France afforded more; and that the Rhenish wines afforded the purest and the greatest quantity.

Tartar is distinguished from its colour into red or white: the first is afforded by red wine.

The purest tartar exhibits an imperfectly crystallized appearance; the form is the same as Chapral has assigned to the acidulous tartrate of pot-ash; and it is this quality which is called grained tartar (*tartre grenu*) in the refineries at Montpellier.

The taste of tartar is acid and vinous. One ounce of water, at the temperature of ten degrees above 0 of Reaumur, dissolves no more than ten grains, according to Chaptal. Others however affirm, that it takes up near twice that quantity. Boiling water dissolves more, but it falls down in crystals by cooling.



Tartar is purified from an abundant extractive principle, by processes which are executed at Montpellier and at Venice.

The following is the process used at Montpellier: The tartar is dissolved in water, and suffered to crystallize by cooling. The crystals are then boiled in another vessel, with the addition of five or six pounds of the white argillaceous earth of Murviel to each quintal of the salt. After this boiling with the earth, a very white salt is obtained by evaporation, which is known by the name of cream of tartar, or the acidulous tartrite of pot-ash, according to the new Nomenclature.

M. Desmaretz has informed us (*Journal de Phys.* 1771) that the process used at Venice consists, 1. in drying the tartar in iron boilers; 2. pounding it, and dissolving it in hot water, which by cooling affords purer crystals; 3. re-dissolving these crystals in water, and clarifying the solution by whites of eggs and ashes.

The process of Montpellier is preferable to that of Venice. The addition of the ashes introduces a foreign salt, which alters the purity of the product. See ACID OF TARTAR.

TERRAS. See TARRAS.

TERRE VERTE. This is used as a pigment, and contains iron in some unknown state, mixed with clay, and sometimes with chalk and pyrites; alum and selenite are also accidentally found with it. It is difficultly soluble in acids, is not magnetic before calcination, and becomes of a coffee colour when heated. It is said to afford about 40 per cent. of iron.

THERMOMETER. In the present cultivated state of philosophical knowledge, it can hardly be supposed that the reader has not seen a thermometer. Minute description is therefore unnecessary. But as the accurate construction and subsequent improvement of this instrument must greatly depend on the knowledge which those who use it may possess of the method of making it; and as we have no perfect account of this, there can be no doubt but a short relation of the whole process, from experimental knowledge, will be acceptable.

The tubes may be had at the glass-house; and the first care of the artist must consist in examining if their cavities be equal or cylindrical throughout. This is done by immersing one end into mercury, and withdrawing it, after closing the other end with the finger. By this means a small quantity of mercury will enter the tube, which will occupy a longer space the deeper the tube is immersed. Lay the tube horizontally upon a graduated rule, and observe the length of the mercurial column in different parts of the tube, to which it may be made to run by inclining it more or less. If the length continues invariably the same, it is a proof that the tube is uniformly cylindrical; but if otherwise, the diameter varies, and the tube cannot be used to make a good thermometer, unless the graduations in the different parts of the tube be lengthened or shortened, in proportion to the measures of the mercurial column.

Direct the flame of a large candle, a watch-maker's lamp, or, which is cleanest and best of all, a lamp with spirits of wine, upon one end of the glass tube, by means of the blow-pipe. The extremity will soon become red hot, and in a state of imperfect fusion. Remove the tube from the flame, and blow into its other end, and the heated part will be inflated so as to form a bulb. This last inflation is the most difficult and laborious part of the business; but it may be performed with great ease and advantage, by previously fastening the neck of one of the small bottles of elastic gum, or India rubber, about the end

of the tube ; which, when the other end is ignited, may be pressed by the hand, so as to blow the bulb very commodiously, and without the introduction of any moist air.

Immerse the open end of the thermometer tube into some very clean dry mercury that has been boiled, and warm the bulb with a candle ; part of the air will be immediately heard rushing through the mercury ; withdraw the candle, and as the bulb cools the mercury will rise in the tube. This will be facilitated by holding the tube as near an horizontal position as can be done, without raising its lower end above the surface of the mercury. In this way the bulb will be nearly half filled. Without altering the position of the apparatus, move the whole so that the bulb may be held over a candle. A small candle newly snuffed is best, because of the steadiness of its flame ; and it will be necessary to wrap a piece of paper round the tube, to defend the finger and thumb from its heat. The mercury will soon boil, and most of the remaining air will be heard escaping from the bulb. As soon as this escape has ceased, remove the bulb from the candle, and it will be suddenly filled with mercury from the vessel.

Take the thermometer thus filled out of the mercury, and wrap round its open end a piece of thin paper, in such a manner as to leave a cavity beyond the tube, at least sufficient to hold as much mercury as the bulb contains ; secure this by wrapping it tight with packthread about the tube ; then put a drop of mercury into the proper cavity, and apply the bulb again over the snuffed candle, holding the tube upright between the finger and thumb, or a pair of small pincers, at the part wrapped with paper and packthread ; the mercury will soon boil, and about half the contents of the bulb will rush violently up the tube into the paper. Remove the bulb from the candle, and the mercury will suddenly return ; then boil it again, and repeat the operation till the speedy boiling of the mercury, when placed over the candle, and the diminished noise and agitation, shew that the whole has been well heated, and deprived of the air or moisture which might have adhered to it.

The operation of boiling will fail, if the mercury or the inside of the bulb be moist ; for in this case the bulb is usually burst by the mercurial vapour ; the explosion however is not dangerous : it is very likely to happen with bulbs blown by the mouth, unless they be kept some weeks in a dry place before they are filled. The same danger makes it prudent not to boil the mercury strongly the first or second time ; and it is likewise of importance to keep the bulb clear of the flame, as the contact of this last against the empty part of the bulb would melt it, and a hole would be immediately made by the excluded vapour.

After the boiling is completed, plunge the bulb into cold water whose temperature is known. Melting ice or snow (or snow and water) always has the temperature of 32° of Fahrenheit's scale. Then take off the paper, and put the bulb into the hand, and afterwards into the mouth ; this heating will cause some of the mercury to drop out of the tube. Cool it again to 32°, by immersing it in the cold water, and mark where the mercury stands. The distance between this station and the top of the tube measures the interval between freezing and blood heat, or 32 and 95, which makes 63 degrees ; and will consequently shew whether the degrees will be large or small, and what extent the scale is capable of ; that is to say, it will shew whether the bulb is of the proper size. This last, supposing the judgment of the operator not sufficient to proportion the bulb nearly to the tube and the intended scale, might however have been  
more



more conveniently ascertained after the first filling, before the boiling had been undertaken.

When the number of degrees to which the length of the tube will extend is thus known, the operator must settle whereabouts he will have the freezing point, which may be nearer or farther from the bulb, accordingly as he intends the instrument to be used, more particularly to ascertain great degrees of heat or of cold. At this stage of the business, likewise, he may heat the upper part of the tube with the blow-pipe, and draw it out to a fine capillary tube ready for sealing. The bulb must then be heated in the candle, till a few particles of mercury have fallen off the top of the tube; and notice must then be taken how much nearer the freezing point is to the bulb than before, which may be done by immersing it in the melting snow as before. If it be not as low as desired, the heating must be repeated, carefully observing not to throw out too much mercury at a time. When the due quantity of mercury is thus adjusted, two candles must be prepared, the one to heat the bulb, and the other to close the tube. The blow-pipe being in readiness, the upper part of the tube near the flame of one candle, and the bulb near the flame of the other, the mercury will rise, and at last begin to form a globule at the point of the capillary tube. At this instant the bulb must be withdrawn from the lower candle, at the same time that the flame of the upper is directed by the blow-pipe upon the point of the tube. This last will be immediately ignited, and will close by the melting of its parts, before the mercury has perceptibly subsided. When the mercury has fallen, this closure may be rendered more secure from accidental breaking, by fusing the whole point of the tube till it becomes round.

If this business be properly done, the mercury in the instrument thus filled will run backwards and forwards in the tube, immediately upon inverting its situation.

In the original graduation of thermometers, two fixed points of temperature are necessary. These are the freezing point of water, or temperature of ice or snow, at the instant of formation, or rather when it is just beginning to liquefy; and the boiling point of water, or temperature at which, under a known pressure, it is plentifully converted into steam. For the settling the freezing point, nothing more is necessary than to immerse the thermometer so deep in melting snow or ice, as that the mercury may be barely visible above its surface, and carefully mark the place at which it stands. The boiling point is not quite so easily ascertained; crude, hard, or saline waters acquire a greater heat in boiling than such as are purer; and the same water will acquire a greater heat under a greater pressure. For this last reason, the boiling point should be fixed according to the decision of the committee of the Royal Society; namely, when the barometer stands at 29,8 inches. The best method is to provide a vessel somewhat longer than the thermometer, with a cover, and two holes in it; one about an inch in diameter, for the steam to escape; and the other smaller, for the thermometer tube to be fastened in it. When this is used, the thermometer must be fastened in the cover, so that the estimated place of the boiling point may be just above the hole. Water must be put in the vessel, not sufficient to touch the bulb of the thermometer when the cover shall be put on. The vessel must then be covered, a thin plate of metal laid on the steam-hole, and the water made to boil by heat applied to the bottom only. The thermometer will be then surrounded with steam, which will raise its temperature to the boiling point; and this point must be carefully marked on the tube. The following method may be more convenient

convenient to those who are not provided with such a vessel: Wrap several folds of linen rags or flannel round the tube, nearly as high as the supposed boiling point; hold the ball of the thermometer in the ascending current of boiling rain-water, about two or three inches below the surface; pour boiling water on the rags three or four times, waiting a few seconds between each time; and wait some seconds after the last time of pouring on water, in order that the water may recover its full strength of boiling, which is considerably checked by the pouring on the rags. The place where the mercury stands is the boiling-water point.

Notwithstanding the accurate adjustment of the fixed points of a thermometer, yet if the tube be not truly cylindrical, or if the divisions be not adjusted to the inequalities of its diameter, the errors at the middle, between the two fixed points, may amount to more than a whole degree. A small error in the standing of thermometers may be occasioned by the varying pressure of the atmosphere, which alters the capacity of the glass; but it never amounts to so much as the tenth part of a degree. Spherical bulbs are least subject to this.

Thermometers which from the great length of their degrees, or for any other reason, are made to take in but a small part of the interval between the two fixed points, are usually graduated by comparison with a standard thermometer.

The very careful boiling of the mercury, as above described, is absolutely necessary for such thermometers as are to be sealed when full; for if there were any air or moisture left in the bulb, it would prevent the mercury in the tube from descending into the bulb, so that the tube would continue always full. These thermometers are undoubtedly the best; but the vacuum above the mercury does not seem to be an indispensable requisite. If a clean dry tube be filled with pure boiled mercury, and a small bulb be left at the top of the tube, to contain common air, in order that its expansion or condensation, produced by the change in the mercurial surface, may be inconsiderable; there will be few practical objections against such a thermometer; more especially if it be a secondary instrument, graduated by means of a standard. There are some thermometers made with tubes so very small, and bulbs so large in proportion to them, that they will not admit of boiling the mercury in them, but are filled with boiled mercury by means of a condenser. These are necessarily of the kind here mentioned.

The thermometers most in use at present are Fahrenheit's, Reaumur's, and Celsius's. In Fahrenheit's scale the number of degrees between the freezing and boiling water point is 180; the freezing point being at 32°, and the boiling point at 212°, both above 0°, or the part from which the degrees are reckoned both ways. In Reaumur's scale, the number of degrees between these two points is 80, and the freezing point is called 0°, from which the degrees are reckoned both ways. In Celsius's thermometer, the interval is divided into 100°, and the freezing point is called 0°, as in Reaumur's. To reduce these scales to each other, it must be observed, that one degree of Fahrenheit's is equal to  $\frac{4}{9}$  of a degree of Reaumur, and to  $\frac{5}{9}$  of a degree of Celsius. Therefore, if the number of degrees of Fahrenheit, reckoned above or below the freezing point, be multiplied by 4, and divided by 9, the quotient will be the corresponding number on Reaumur's scale. Or if the multiplier 5 and the divisor 9 be used, the quotient will give the degrees of Celsius's scale. And,

contrariwise,



contrariwise, if any number of degrees, either of Reaumur or Celsius, be multiplied by 9, and divided by 4 if of Reaumur, or by 5 if of Celsius, the quotient will give the degrees of Fahrenheit, reckoned either above or below the freezing point, as the case may be.

TIN is a metal of a yellowish-white colour, considerably harder than lead, scarcely at all sonorous, very malleable, though not very tenacious. Wires cannot be made of it; but under the hammer it is extended into leaves, called tin foil, which are about one-thousandth of an inch thick, and might easily be beaten to less than half that thickness, if the purposes of trade required it. The process for making tin foil consists simply in hammering out a number of plates of this metal, laid together upon a smooth block, or plate of iron. The smallest sheets are the thinnest. Its specific gravity is less than that of any other malleable metal. Long before ignition, it melts at about the 410th degree of Fahrenheit's thermometer, and by a continuance of the heat it is slowly converted into a white powder by calcination. Like lead, it is brittle when heated almost to fusion, and exhibits a grained or fibrous texture, if broken by the blow of a hammer; it may also be granulated by agitation at the time of its transition from the fluid to the solid state. The calx of tin resists fusion more strongly than that of any other metal; from which property, it is useful to form an opaque white enamel when mixed with pure glass in fusion. The brightness of its surface when scraped, soon goes off by exposure to the air; but it is not subject to rust or corrosion by exposure to the weather.

Concentrated vitriolic acid, assisted by heat, dissolves half its weight of tin, at the same time that vitriolic acid air escapes in great plenty. By the addition of water a calx of tin is precipitated. Vitriolic acid, slightly diluted, likewise acts upon this metal; but if much water be present, the solution does not take place. In the vitriolic solution of tin there is an actual formation, or extrication of sulphur, which renders the fluid of a brown colour whilst it continues heated, but subsides by cooling. The tin is likewise precipitated in the form of a white calx by a continuance of the heat, or by long standing without heat. This solution affords needle-formed crystals by cooling.

Nitrous acid and tin combine together very rapidly, without the assistance of heat. Most of the metal falls down in the form of a white calx, extremely difficult of reduction; and the small portion of tin which remains suspended, does not afford crystals, but falls down, for the most part, upon the application of heat, to inspissate the fluid. The strong action of the nitrous acid upon tin produces a singular phenomenon, which is happily accounted for by the modern discoveries in chemistry. M. de Morveau\* has observed, that, in a solution of tin by the nitrous acid, no elastic fluid was disengaged, but that volatile alkali was formed. This alkali must have been produced by the phlogisticated air of that part of the nitrous acid which was employed in affording pure air to calcine the tin. The phlogisticated air must therefore have combined with inflammable air; but whether this inflammable air was afforded by a decomposition of the water of the menstruum, or whether it came from the phlogiston of the tin, is a question that must remain undetermined, until decisive experiments have been made for the establishment of one or the other of the two theories, which at present divide the chemical world.

The marine acid dissolves tin very readily, at the same time that it becomes of

\* Kirwan on Phlogiston, 2d edition, p. 234.

a darker colour, and ceases to emit fumes. A slight effervescence takes place with the disengagement of a fetid inflammable gas. Marine acid suspends half its weight of tin, and does not let it fall by repose. It affords permanent crystals by evaporation. If the tin contain arsenic, it remains undissolved at the bottom of the fluid.

Dephlogisticated marine acid dissolves tin very readily, and without sensible effervescence. The solution itself does not appear to differ from the foregoing.

Aqua regia, consisting of two parts nitrous and one marine acid, combines with tin with effervescence, and the development of much heat. In order to obtain a permanent solution of tin in this acid, it is necessary to add the metal by small portions at a time; so that the one portion may be entirely dissolved before the next piece is added. Aqua regia, in this manner, dissolves half its weight of tin. The solution is of a reddish brown, and in many instances assumes the form of a concrete gelatinous substance. The addition of water sometimes produces the concrete form in this solution, which is then of an opal colour, on account of the calx of tin diffused through its substance. The uncertainty attending these experiments, with the solution of tin in aqua regia, seems to depend upon the want of a sufficient degree of accuracy in ascertaining the specific gravities of the two acids which are mixed, the quantities of each, and of the tin, together with that of the water added. It is probable that the spontaneous assumption of the concrete state depends upon water imbibed from the atmosphere. The solution of tin in aqua regia is used by degrees to heighten the colours of cochineal, gum lac, and some other red tinctures, from crimson to a bright scarlet, in the dying of woollens.

M. Hermstädt has succeeded in the actual acidification of this metal, by treating it with the marine and nitrous acids. He dissolves pure tin in pure marine acid, and boils this solution with nitrous acid (distilled from manganese), until the red vapours cease to appear. The fluid, which is then limpid, is exposed to distillation, until the whole of the marine and nitrous acids have been dissipated. The white remaining mass is soluble in three parts of water, and is the acid of tin. A red heat converts this matter into a yellow transparent substance, neither acid nor soluble in water; but it regains both properties by a few weeks exposure to the air\*.

The acetous acid scarcely acts upon tin. The operation of other acids upon this metal has been little enquired into.

When equal parts of an amalgam of tin and mercury, and of corrosive sublimate, are triturated together, and the mixture exposed to distillation in a retort, by a very gentle heat; a colourless fluid first comes over, which is followed by a thick white fume, which becomes condensed into a transparent liquor, called the fuming liquor of Libavius, on account of the copious fumes it emits when the vessel that contains it is opened. On account of the considerable volatility of this liquid, it rises partly in the form of flowers to the top of the bottle in which it is put; so that, in the course of several months, it becomes entirely closed. The composition and effects of this liquid were but imperfectly known until lately, when Mr. Adet made several ingenious experiments upon it. By exposing this liquid under receivers containing dry air, over mercury, he found that the volatile fluid arose, and lined the vessel with crystals, when water was present, though very few crystals were formed when the air was as dry as it could

\* Journal de Phys. xxxv. 391. Nov. 1789.



be made. He observed likewise, that when water was added to the fuming liquor of Libavius, it became solid, and ceased to emit fumes. A precise quantity of water is required to produce this effect in the most perfect manner. If the quantity of water be too small, the liquor retains more or less of its disposition for the fluid state; and if it be too considerable, the fluidity of the water prevails. By several trials he found, that the due proportion of water to be added to the fuming liquor of Libavius was 7 to 22. A kind of ebullition, or escape of bubbles, was produced during the combination; which, on examination, was found to arise from the escape of the air previously contained in the fluid water. He found likewise, that this concrete substance, when rendered fluid by an increase of temperature, was capable of dissolving more tin, without the disengagement of inflammable air. After the concrete substance was saturated with tin, it could no longer be sublimed, but might be made to undergo a red heat, during which time there was an escape of vapours, consisting of tin combined with the marine acid; and after a strong heat, the residue was a white calx of tin. It appeared therefore, that the liquor of Libavius, rendered concrete by water, and saturated with tin, resembles in its properties the common solution of tin in the marine acid.

From these circumstances Mr. Adet concludes, that the tin, by stronger affinity, combines with the aerated or dephlogisticated marine acid of the corrosive sublimate with which it is heated; that this combination contains no water; and that, as it abounds with a substance of such extreme volatility as that aerated acid, its freezing point is very low, inasmuch that it is habitually fluid; that the addition of water, in a due proportion, alters the freezing point, and renders it concrete at a common temperature; and lastly, that the state of the marine acid in this substance is that which is called aerated, or dephlogisticated; which is proved, as well from the experiments which ascertain that state in corrosive sublimate, as from similar experiments with the fuming liquor, which, as has been observed, is capable of dissolving more tin without disengaging inflammable air; the fuming liquor of Libavius has therefore the same relation to the common solution of tin as corrosive sublimate has to calomel.

The residue, after the distillation by which the fuming liquor of Libavius is produced, consists of tin combined with the marine acid, calomel, and running mercury, which sublime into the roof and neck of the retort; and at the bottom is found an amalgam of mercury and tin, covered with a saline combination of marine acid with tin, and such other metals as the tin may have been adulterated with. Much information may be derived from the foregoing experiments of Mr. Adet respecting the phenomena produced when tin is dissolved in aqua regia.

Earthy substances do not appear to affect this metal in the dry way. It detonates very rapidly with nitre, and becomes converted into a calx, which partly combines with the alkali. All the vitriolic salts are decomposed by tin. The tin becomes calcined, and the vitriolic acid converted into sulphur, either by the phlogiston of the metal, according to the ancient theory, or by the subtraction of its vital air, according to the modern theory. This sulphur appears to combine with the alkali, or earth of the salt, with which it forms an hepar that dissolves part of the calx.

Sal ammoniac is very readily decomposed by tin. Alkaline and inflammable air are disengaged, and a concrete marine salt remains behind, which in some mea-

fire resembles the fuming liquor of Libavius. The volatile alkali, or alkaline air, which escapes, is disengaged by virtue of the superior affinity of the calx of tin with the marine acid, at the temperature of the experiment. The inflammable air, which likewise flies off, is a consequence of the calcination of the tin, or the decomposition of the water, according to the theory which may be applied in the explanation. Notwithstanding the facility with which this metal decomposes sal ammoniac, there is an inconvenience resulting from its use which depends on the great fusibility of this metal; in consequence of which, it cannot be intimately mixed with the sal ammoniac, but remains at the bottom of the vessel in the fluid state, while part of the sal ammoniac eludes its action, and is sublimed entire.

If the crystals of the saline combination of copper with the nitrous acid be grossly powdered, moistened, and rolled up in tin-foil, the salt deliquesces, nitrous fumes are emitted, the mass becomes hot, and suddenly takes fire. In this experiment\* the rapid transition of the nitrous acid to the tin, is supposed to produce or develope heat enough to set fire to the nitrous salts; but by what particular changes of capacity has not been shewn.

If sulphur, in powder, be added to about five times its weight of melted tin, the two substances combine, and form a black compound, which takes fire, and is much less easily fused than tin itself. The mass is brittle, and of a needled texture.

The combination of tin and sulphur forms a compound called *aurum musivum*, which see.

When tin is heated with phosphoric acid and charcoal, the metal appears to be very little changed. A combination, however, seems to take place; for the phosphorus burns on the surface of the metal when heated by the blow-pipe.

Tin unites with bismuth by fusion, and becomes harder and more brittle in proportion to the quantity of semi-metal added. With nickel it forms a white brilliant mass. It cannot easily be united in the direct way with arsenic, on account of the volatility of this semi-metal; but by heating it with the combination of the arsenical acid and vegetable alkali, the salt is partly decomposed; and the tin combining with the acid becomes converted into a brilliant brittle compound, of a plated texture. It is thought that all tin contains arsenic; and that the crackling noise which is heard upon bending pieces of tin, is produced by this impurity. Cobalt unites with tin by fusion; and forms a grained mixture of a colour slightly inclining to violet. Zinc unites very well with tin, increasing its hardness, and diminishing its ductility, in proportion as the quantity of zinc is greater. This is one of the principal additions used in making pewter, which consists for the most part of tin. The best pewter does not contain above one-twentieth part of admixture, which consists of zinc, copper, bismuth, or such other metallic substances as experience has shewn to be most conducive to the improvement of its hardness and colour. The inferior sorts of pewter, more especially those used abroad, contain much lead, have a blueish colour, and are soft. The tin usually met with in commerce in this country, has no admixture to impair its purity, except such as may accidentally elude the workmen at the mines. But the tin met with in foreign countries is so much debased by the dealers in that article, especially the Dutch, that pewter and tin are considered abroad as the same substance. Regulus of antimony forms a very brittle, hard mixture with tin; the specific gravity of which is less than would have been de-

\* Of Dr. Higgins, Philof. Trans. lxxiii. p. 137.



duced by computation from the specific gravities and quantities of each, separately taken. Wolfram fused with twice its weight of tin affords a brown spongy calx, which is somewhat ductile.

Tin is scarcely ever found native. Native tin may be analysed in the moist way, by the application of nitrous acid, which calcines the tin, and dissolves the other metals it may contain. One hundred and forty grains of the washed and dried calx are equivalent to one hundred grains of metallic tin. The metallic admixtures may be separated from the nitrous acid, by methods adapted to their respective properties; which may be easily gathered from what has been observed in the humid analysis of the metals before treated of.

The calciform ores of tin are—tin spar, which is generally of a whitish or gray colour, sometimes greenish or yellowish, semi-transparent, and crystallized in a pyramidal form, or irregularly—opaque brown or black tin ore, crystallized and embodied in quartz, fluor, or mica, or mixed with white and yellow pyrites; these ores contain a mixture of iron—the reddish-yellow, or garnet ore, which contains more of iron than tin—and the tin-stone, vulgarly called load-stones, which contain still less tin. See ORES OF TIN.

It was formerly supposed that tin was frequently mineralized by arsenic; but it is now admitted, that the arsenic which may be contained in tin is afforded by the matrix. The scarcity of sulphureous tin ores was likewise considered, till lately, as a very singular fact, on account of the facility with which that substance unites to tin: such combinations however have since been found. The native aurum musivum, from Siberia, is of this kind: and a very considerable vein of tin in combination with sulphur, and an admixture of copper and iron, has been found in Cornwall\*. The analysis of tin ores in the humid way is an object of some difficulty; because they are not acted upon effectually either by the vitriolic, nitrous, or marine acids, or by an aqua regia. The method of Bergman is as follows: The ore must be reduced to a very subtle powder by levigation and elutriation. This last process consists in agitating any powder in water, which is heavy enough to sink in that fluid. The particles will be resisted in their descent, according to the surfaces they oppose against the fluid. It is scarcely necessary to observe, that a larger body presents a less surface to be resisted, than the same body would oppose if it were divided into parts. For this reason, when a powder consisting of particles of the same density, but different magnitudes, is agitated in a lighter fluid, the largest pieces come first to the bottom: and hence the method of elutriation enables us to assort the various particles of a powder according to their magnitudes, by first agitating the fluid, and successively decanting it into different vessels. Thus, for example, if the water be decanted five seconds after the agitation, it will leave a powder behind it; if it be again decanted at the end of five seconds more, the second vessel will contain a much finer powder than the foregoing; and, by a third decantation, a still more subtle powder will be obtained. This is the method applied in the preparation of the white calx of tin, called putty, and used for polishing fine metallic speculums, and the object lenses of telescopes; and in this way the tin ore to be analysed may be reduced to a very subtle powder, by levigating and again washing the coarse residue which subsides in the first vessel. It may be observed, that the successive decantations are un-

\* See Magellan's Cronstedt, p. 637. The contents of one specimen were 30 parts sulphur, 41 tin, 43 copper, 2 iron, and 3 stony matrix.

necessary where the very finest powder only is wanting; because this may be as well obtained by suffering the water to stand a sufficient time before it is decanted off at first. To the very subtile powder of tin ore, thus afforded, a quantity of concentrated vitriolic acid must be added, and kept in a strong digesting heat for several hours. A small portion of concentrated marine acid must be poured into this when cold. A strong effervescence takes place with considerable heat, and the escape of marine acid air, which has been deprived of its water by the vitriolic acid. After the expiration of an hour or two, some water must be added, and the clear liquor decanted. The same operation must be repeated with the residuum, until the acids can dissolve no more; and nothing will then remain but the stony matrix. The solution, when precipitated by means of mild alkali, will afford 100 grains of metallic tin for each 132 grains of precipitate, when washed and dried. If the precipitate do not consist of pure tin, but contain copper or iron, it must be calcined for an hour in a red heat; then digested in nitrous acid, which will take up the copper; and afterwards in marine acid, which will dissolve the iron.

In the dry way, after pulverization, and separation of the stony matter by washing, the tin ores may be hastily fused with twice their weight of a mixture of pitch and calcined borax, in a crucible lined with charcoal, and covered; or the ore may be mixed with twice its weight of tartar, one part of black flux, and half a part of resin. This mixture being then divided into three parts, each part must be successively projected into a crucible ignited to whiteness, which must be immediately covered as soon as the portion thrown in ceases to flame.

The operation of reducing tin ores in the large way, is conducted upon similar principles. When impure, they are cleansed from foreign admixtures, by sorting, pounding, and washing. A slight previous roasting renders the stony parts more friable; and when arsenic is contained in the matrix, it is driven off by a strong heat, continued for a short time; the ore being frequently stirred, to prevent its running together by fusion. In the smelting of the ore, care is taken to add a larger quantity of fuel than is usual in the reviving of other metals; and to avoid a greater heat than is necessary to reduce the ore, in order that the loss by calcination may be prevented as much as possible. See ORES, p. 609.

Tin is a metal which, as far as our present information extends, is not very much diffused. It is found in Bohemia and Saxony, and on the island of Malacca in the East Indies. But the largest quantities, at least for the European consumption, are found in England; particularly in the county of Cornwall. This island has been famous for its tin mines from the remotest periods of history; and would not, probably, have been frequented by the ancient Phœnician navigators, if they had not been attracted hither by the great plenty of tin with which it abounds. Several etymologists have endeavoured to shew, that the name of Britain is derived from a word common to the Syrian and Chaldean languages, denoting tin; but on this no great stress can be laid.

The uses of tin are very numerous, and so well known, that they scarcely need be pointed out. Several of them have been already mentioned. The tinning of iron and copper, the silvering of looking-glasses, and the fabrication of a great variety of vessels and utensils for domestic and other uses, are among the advantages derived from this metal.

**TINCAL.** Crude borax, as it is imported from the East Indies in yellow greasy crystals, is called tincal. Its origin was long unknown, or related in such a manner



a manner by travellers, that philosophical enquiries seemed to have given them little credit. For several authentic accounts, see the article BORAX. Mr. Hoefer, who ascertained the existence of the acid of borax in certain lakes in Tuscany, published an express treatise on this subject in the year 1778, which I have not seen, but of which a short extract is given in the Journal de Physique for June 1779. Several of his narratives respecting its origin agree with those inserted in the article last referred to. He mentions as a fact, that the Thibetians draw off the waters of certain lakes, for the purpose of obtaining the crystals which are found among the mud at the bottom, and that this mud emits dangerous and very caustic exhalations.

The method of refining borax in Holland, according to him, is as follows: One hundred pounds of crude borax from India afford eighty pounds of the refined sort. The impure salt is very difficult of solution. Double the weight of hot water is added to a given weight of the salt, and afterwards decanted off. A like quantity of hot water is again added, and these equal additions of water and decantations are repeatedly made for eight or ten times before the whole of the saline matter is extracted. By this means eight or ten crystallizations of borax are obtained, which differ from each other in colour, figure, transparency, and weight. After the crude borax is thus deprived of the foreign earthy and stony matters, it is disposed for solution by macerating it in its own weight of hot water during eight days. I suppose of course that water is to be added to supply the loss by evaporation during this time. Each solution is then poured boiling hot through a woollen strainer supported on brass wire work. The first solutions are made slowly, and are reddish. The latter are scarcely coloured, and require less time. The hot liquor is then poured very hot into a leaden vessel in the form of a very large crucible, in which it is evaporated by a slow fire. It is then set aside, surrounded with a large quantity of finely minced straw; a wooden cover faced with lead is placed on it, and the whole is covered up with mats and cloths. These precautions keep the fluid hot a long time, and facilitate the separation of foreign matters as well as the regularity of the crystallization. This last operation continues twenty days, after which the borax is taken out in fine crystals for the market.

**TINCTURES OF VEGETABLE AND ANIMAL SUBSTANCES.** Many medicinal preparations are called tinctures, because they are made by digesting certain vegetable and animal substances in spirit of wine, to which they communicate different colours according to their nature.

Some of these tinctures are made with one vegetable or animal substance only. These are called simple tinctures, and they are distinguished by the name of the vegetable or animal matter employed; such are the tinctures of myrrh, of aloes, of saffron, of castor, and many others.

Others contain a greater or less number of different vegetable and animal substances, which are digested in spirit of wine, according to the several receipts. These have the general name of compound tinctures, and are also distinguished by the names of their particular authors and qualities.

These several tinctures are rather objects of pharmacy than of chemistry. Macquer makes the following general observations upon them.

First, as vegetables and animals are composed of several principles which are not all soluble, or not equally soluble in spirit of wine, we cannot consider spirituous tinctures as complete extracts of the vegetable and animal substances employed in their preparation.

Secondly,

Secondly, the principles of those substances upon which spirit of wine can act, are volatile essential oils, and others of the same nature; resins, properly so called; any oils that are in a saponaceous state, and soluble in water by means of some saline matter; acids; and lastly, several kinds of neutral salts. And the principles which spirit of wine cannot dissolve directly, are sweet oils and oily concretions that are not volatile nor saline; substances purely gelatinous and gummy; earthy matters not saline, nor soluble in water; and lastly, many neutral salts, which are insoluble in spirit of wine, the various kinds of which have not yet been determined.

Thirdly, many of the vegetable and animal principles that are essentially insoluble in spirit of wine, particularly gums, jellies, and neutral salts, are soluble in water.

Fourthly, from the last observation we may perceive, that tinctures drawn from the same vegetable or animal substance must differ considerably, according to the state of dryness of these substances, and the dephlegmation of spirit of wine employed. For a tincture made from moist plants, and with a weak spirit of wine, must contain some gummy and saline principles, which could not be contained in a tincture made with the plants perfectly dried and a spirit of wine perfectly rectified.

Fifthly, as many chemical experiments shew that substances naturally insoluble in any certain menstruum, may be rendered soluble in that menstruum by some other intermediate substance; and as amongst the vegetable and animal principles, some such intermediate substances may exist; it cannot therefore be affirmed, that spirituous tinctures contain no other of these principles than such as are naturally soluble in spirit of wine; but it seems more probable that they contain other principles. As this subject has not been sufficiently examined, it is impossible to speak upon it in any other than a vague and general manner.

**TINNING OF COPPER AND OF IRON.** Tinning is an operation by which a very thin layer of tin is applied to the surface of some metals, and especially of copper and of iron. The methods of tinning these two metals are different. Copper is tinned after it has been formed into utensils, and by the copper-smiths who form these utensils. The tinning of iron is performed upon thin plates of iron, in particular manufactories in France, England, Germany, and in some other places.

The several operations for tinning of copper and iron are founded, first, on the facility with which tin unites with these metals, which is so great, that when either of these metals is tinned, the tin only requires to be melted; and the others on which it is to be applied do not. Nevertheless, the tin incorporates with these metals, dissolves in some measure their surface, and forms a kind of alloy, at least when the tinning is well performed.

Secondly, the foundation of all the parts of the operation used to make the tinning succeed is, that metals cannot perfectly unite with each other but when they are in a metallic state; and that they cannot unite with any earthy matter, not even with their own earth or calces.

Hence the whole art of tinning consists in employing melted tin, the surface of which shall be very clean, metallic, and not covered with any ashes or calx of tin, to the surface of iron or of copper, which must also be very clean, and free from all rust or calx.

To attain these purposes the following method is used: As the surface of copper is continually altered merely by the action of air, the workmen before the tinning of



of any vessel scrape its surface with a steel instrument till it be clean and bright; then they place the vessel upon kindled coals, and heat it to a certain degree: as soon as it is hot they rub it with pitch; and then apply the melted tin, which they spread upon the surface of the copper by means of hards, or balls of flax. Pure tin is seldom used for this purpose; but generally two parts of tin are alloyed with one part of lead.

The pitch used in this operation is quite necessary, because the degree of heat given to the copper is sufficient to calcine its surface in some measure; and this alteration, however slight, would prevent the perfect adhesion of the tin. This pitch prevents also the slight calcination which would happen on the surface of the tin, or revives the small particles of calx which are formed during the operation.

When plates of iron are to be tinned, they must be perfectly well cleaned, which is done by scouring them with sand, and steeping them some time in an acid liquor: then they are to be wiped, and dried quickly and perfectly. Lastly, they are to be plunged vertically into a vessel containing melted tin, the surface of which is covered with fat and pitch. These fat substances covering the surface of the tin prevent its calcination, by which its adhesion to the iron would be impeded; and also render the surface of the iron, while it passes through them, fitter to receive the tin. By thus plunging plates of iron into melted tin, they are covered over with this metal, or are tinned.

Sal ammoniac is also used successfully in the tinning of iron and copper, and always for the same reason. The acid of this salt perfectly cleans the surface of the metals to be tinned; and the oily matter, or perhaps the inflammable air of the alkali contained in sal ammoniac, prevents the calcination. Thus by heating these metals to a certain degree, and rubbing them with sal ammoniac, the tin may be applied immediately afterwards.

The art of tinning is kept a great secret by the workmen, but does not appear to be in any respect difficult to an ingenious contriver. Thus iron tacks, which cannot be conveniently tinned in a bath, are easily covered with that material by including the nails, with a due proportion of tin and sal ammoniac, in a stone bottle, and agitating them while heating and cooling.

The advantages received from tinning are very considerable. As tin is a soft and fusible metal, vessels formed of it alone would not have sufficient strength and hardness to keep their shape in common use, and would also be liable to be melted with a small heat: but when it is applied to the surface of hard and difficultly fusible metals, as copper and iron, many vessels may be fabricated which have the advantage of being preserved by means of the tin from rust, to which the copper and iron are very subject. It has been nevertheless justly alleged, that copper vessels are not perfectly prevented from rust or verdigrise by tinning; and this fault is so much more important, as tinned copper vessels are used in the preparation of food. These vessels, therefore, even when tinned, ought not to be employed for this purpose: especially as tin itself is suspected of being hurtful to health, since Margraaf discovered that arsenic is contained in almost all tin; and also because lead, a most hurtful metal, is used in tinning. Nevertheless, tinned copper vessels may be used for many other purposes. Besides, the tinning of copper and iron vessels may be improved by attending to the fundamental principles of this art delivered in the present article.

M. Malouin has proposed in his *Memoirs on Zinc* (*Mem. de l'Acad. des Sciences*, 1742) to substitute that semi-metal in place of lead and tin, for the tin-

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ning of iron and copper vessels. The greater hardness of the zinc, it is thought, would render it less liable to be worn; and the dangerous effects of lead and tin would be avoided. But whether it might not be attended with other inconveniences must be submitted to further experience.

For the tinning of looking-glasses, see SILVERING.

The tinning of pins has been the object of a considerable series of investigations by Mr. Gadolin. In the *Journal de Physique* for May and June 1789, there is a translation of his Memoir by Dolfuss, of which the following is an abstract. It is a generally admitted fact, that copper dissolved in any acid whatever is always totally precipitated by the addition of tin. The experiment of whitening pins shews nevertheless that tin is really precipitated in the metallic form by copper, if both be boiled in a solution of tartar. Mr. Gadolin, in the presence of Mr. Gahn, found that the remaining fluid contained no copper; whence these chemists concluded, that the precipitation must be effected in some way different from that of the ordinary elective attraction. He therefore instituted the following experiments:

1. A leaf of tin was kept some days in a solution of half a loth of cream of tartar, after which it was found to have lost 0,005 loth of its weight. A plate of copper, by digestion for six hours in the fluid, after the tin was taken out, lost 0,0006 loth of its weight, but was not visibly altered, excepting that its surface was slightly calcined. The solution was then boiled with polished iron, and both the tin and the copper were precipitated on the iron.
2. The results were nearly the same when acid of tartar was used instead of the cream of tartar.
3. To a solution of tin in aqua regia, soluble tartar was added: the tin fell down in combination with the acid of tartar. Of this precipitate, firstedulcorated and dried, half a loaf was boiled with water and a polished copper-plate for three hours. No remarkable change happened to the copper.
4. The last experiment was repeated with one tenth of a loth of the precipitate, and 0,07 loth of crystallized acid of tartar. The result was as before.
5. Tin foil was then added along with the polished copper in the last-mentioned solution. After three hours boiling the copper became covered with a pellicle of tin, which was rather dull, and had increased in weight 0,0002 loth. The tin lost 0,001 loth.
6. One tenth of a loth of the precipitate N° 3, was boiled for three hours on a plate of copper, with the addition of tin foil. The tin became of a blackish yellow dull colour, with the loss of 0,0009 loth; but the copper was not at all changed.
8. The last-mentioned experiment was made, with the addition of half a loth of cream of tartar to the solution. The tin lost 0,0009 loth of its weight; the copper became covered with a very slight pellicle, and had lost 0,0004 of its weight.
9. Half a loth of cream of tartar, dissolved in water, was boiled with leaves of tin and a plate of polished copper. The copper became covered with a pellicle of tin, and had gained in weight 0,0001 loth. The tin had lost 0,0004 loth.
10. One sixth of a loth of crystallized acid of tartar was dissolved in water, and boiled with leaves of tin and polished copper for three hours: the tin lost 0,0004 loth; but the copper was not changed either in colour or weight.
11. To the last-mentioned solution a quantity of vegetable alkali was added, sufficient to saturate the tartar. A plate of copper and leaves of tin were again added, and the whole boiled a little. The tin thus added lost 0,0005 loth of its weight. The copper was covered with a pellicle of tin, but did not acquire any perceptible increase of weight.
12. One loth of cream of tartar was dissolved in water, and saturated with



with vegetable alkali. In this solution leaves of tin and polished copper were boiled for three hours, at the end of which time the copper was not changed, but the tin had lost 0,0014 of its weight. A few drops of solution of the acid of tartar were then added, and the boiling repeated. The copper became covered with tin. 13. Two thirds of a loth of cream of tartar were dissolved in water, and boiled with a plate of polished copper, the surface of which was covered with a slight pellicle of tin: the copper had lost by that means 0,0062 loth of its weight, in the form of a detached scoria. One part was dissolved, and the rest lay at the bottom of the phial. Into this solution a plate of polished copper was put, with leaves of tin. After three hours the tin and the copper were found covered with a black thick crust, which might have been scaled off. The tin had lost 0,007 loth of its weight by this operation. But the copper had lost nothing, and was covered with an unequal tarnished film of tin. On those parts from which the black pellicle was removed, a slight scale of tin might be perceived. 14. Two thirds of a loth of cream of tartar were dissolved in water, and to this were added 0,005 loth of calx of copper, precipitated from blue vitriol by vegetable alkali. After having boiled in this solution a piece of tin in leaves and polished copper for the space of three hours, the tin became covered with an entire crust, but detached as in the last experiment. After the separation of this crust, the tin weighed 0,0071 loth less than before. The copper was covered with a blackish pellicle, and had gained 0,004 loth of weight. 15. One sixteenth of a loth of crystallized acid of tartar, and 0,0028 loth of precipitated calx of copper. In this solution a plate of polished copper and tin in leaves were boiled for three hours. It was then found that the tin, cleared of its black crust, had lost 0,0056 loth. The copper, which was covered with a black pellicle not detached, had gained 0,0004 loth. 16. In a solution of one sixth of a loth of crystallized acid of tartar in water, a piece of iron was boiled during half an hour, and lost 0,002 by solution. Into this clear solution a piece of polished copper and leaves of tin were put, and boiled for three hours. The copper became covered with a bright pellicle of tin, without any remarkable acquisition of weight. The tin had lost 0,0004 loth.

The reasoning of Mr. Gadolin on these experiments is premised by two observations: 1. That in all calcination of metals, a common substance unites with and becomes a component part of the calx, which to avoid reference to every theory he calls the calcining matter. 2. That a metal is calcinable in different degrees, and is disposed to combine with a greater portion of calcining matter, or to part with some of that which it already holds, accordingly as that quantity is less or greater. He then proceeds to infer,

That copper can never separate metallic tin from a solution of tin in tartar, or its acid, if metallic tin itself be not at the same time present.

That the solution of tin is made in the acid of tartar by a calcination of that metal; that the copper tends to attract and combine with the dissolved metal, but cannot separate it from the calcined matter; but that the calcining matter having a tendency to unite with the metallic tin already present in the mass, is by this means solicited to quit the dissolved tin, which it does in part. The consequence is, that a small portion of the tin combines with the copper in the metallic state, and another portion of tin is taken up, accurately sufficient to set the several tendencies in equilibrio.

This precipitation does not take place when the acid of tartar predominates greatly, and still less if the solution be saturated with a calx of tin in a higher state of

of calcination. For in the first case the unsaturated acid retains the tin by a power too strong to be overcome by the attraction of the copper, and in the latter case the calcining matter acts on the tin nearly in the same way.

The precipitation of the tin takes place, if the acid of tartar has recently dissolved a small portion of iron in the metallic state. For iron recently dissolved is very strongly disposed to combine with the calcining matter, and by that means favours the reduction of the tin.

M. Gadolin further remarks, that tin is more abundantly dissolved in tartar, or its acid, if tin in a state of higher calcination be previously dissolved; and that the action of the acid is still more effectual, if the calx of copper be previously dissolved in it. And in this case the metallic copper presented is covered with a dirty pellicle. In these experiments (13, 14, 15) the metals previously dissolved are precipitated in the metallic state. And hence it is seen that those who are engaged in this business ought to be careful to avoid any impurity or scoria of copper in their mixtures.

From the ingenious solution this chemist affords to the difficulty attending the precipitation of tin by copper in this process, by the attraction existing between the two metals and the different degrees of calcination, it is evident how important it is to pay a due attention to all the circumstances of chemical operations, and particularly this last. The Baron de Gedda on this occasion made several experiments, which led to a closer investigation on the part of Professor Gadolin.

The Baron whitened copper by boiling it with tartar and tin. He also tried alum and common salt, together and separately. The alum answered particularly well. His remarks on the theory of the Professor were, in short, that the subject did not appear to be sufficiently mature to admit of a clear explanation, particularly as the effect is attributed to a simple attraction, and ought to succeed with an addition of iron, after taking out the metallic tin, which he tried in various ways without success.

In his second set of experiments, M. Gadolin shews more strongly that the copper need not be acted on by the acid in the process, by repeating the experiments with cream of tartar, tin, and a piece of fine gold. The gold was well tinned, though the acid of tartar had assuredly no action on it.

With regard to the precipitation of the tin upon the copper by the addition of iron, after the leaves of tin were taken out, he did not indeed find it take place in trials with the acid of tartar, which he attributed to the slight action of this acid. And accordingly he found that it succeeded when tin and alum were boiled together; the tin then taken out, and a plate of copper boiled in the solution, with a few filings of iron. The iron was strongly acted on, and the copper in a few minutes covered with a pellicle of tin.

The following experiments tend also to throw further light on the subject. One part of tin in leaves was added to two parts of vitriol of copper dissolved in water. The mixture was kept in a close phial for several days, in a moderate heat and occasionally agitated. After some days the green colour had disappeared, the copper had fallen down, and the solution by the test of volatile alkali gave an abundant precipitate of calx of tin, but no trace of copper. Of this vitriolic solution of tin one part was added to a plate of copper and leaves of tin; a second part was added to a plate of copper and another of iron; and the third was added to a plate of copper alone. These three mixtures, in separate phials, quite full and well closed, were kept in a moderate heat for some hours; after which the copper in the first was found to be covered with an even polished pellicle of tin, but a



little dull and blueish. In the second the copper was also tinned, but less uniformly; and the iron was every where well covered. In the third the copper was not at all changed.

The solutions in the first set of experiments, which contained copper, and were unfit for this operation, were rendered fit for the purpose by first precipitating the copper by ebullition with tin. The same effect took place with the aluminous solution of tin contaminated with copper.

Unequal proportions of tartar, alum, and common salt, are used in the arts for whitening copper. When a bright and shining surface is required rather than an high degree of whiteness, the solution of tartar is to be preferred. The solution of alum gives merely an exquisite whiteness, and is to be preferred where a clear dead white, as it is called, is wanted. Tartar and common salt are added to diminish the appearance of want of polish the solution of alum gives to the blanché metal. Gadow found that a mixture of one part of white tartar or cream of tartar, two of alum, and two of common salt, is the most useful solvent for this purpose, and very well calculated to succeed.

TOBACCO (*Petum*, *Nicotiana*, *herba medicea*, &c.) was first discovered in the island Tobago; brought into Europe in the year 1559 or 1560, by Mr. Nicot the French ambassador in Portugal, and presented to queen Catherine de Medicis. It is now become the object of very extensive manufactures, and cultivated in large quantity by the European colonies in America, as also in some parts of Europe. There are different species of the plant, and great differences also in the qualities of one species according to the soil and climate: still further differences are occasioned in the prepared tobaccos and snuffs from the manner of preparation, and the additions made use of for communicating colour, flavour, &c.

The leaves of this plant, taken internally, prove virulently emetic, cathartic, and narcotic: even in the common forms in which they are employed in such immense quantities, they generally at first disorder the constitution, till habitual use, which subdues many noxious things, has rendered them perhaps innocent, and perhaps even necessary. Distilled in a retort without addition, they yield an acrid empyreumatic oil, which has been found from repeated trials to be poisonous to sundry animals: it is probably on this oil that the effects of the smoke of tobacco depend, for when the plant is set on fire, its native qualities are destroyed.

Tobacco loses its virulence by long coction in water, though all the active parts of the herb are extracted by the water; yet the extract left upon evaporating the liquor, taken in doses of four or five grains, proves mildly aperient and anodyne, and is said to be of great service in disorders of the breast: the longer the coction is continued, a suitable quantity of water being added for that purpose, the milder is the extract.

Neumann analysed three sorts of tobacco, the American canister tobacco, the Dutch leaf, and the dried leaves of our own growth. An ounce of the canister, treated first with water, gave four drams thirty grains of extract; the same quantity of the Dutch, four drams; of our own, four drams fifty grains. From the residuum of the first, rectified spirit extracted thirty grains; from that of the second, sixty; and from that of the third, thirty. An ounce of the canister sort, treated first with rectified spirit, yielded one dram thirty grains; the same quantity of the Dutch, two drams twenty grains; and an ounce of ours, two drams thirty grains. From the residuum of the first, water extracted three

drams thirty grains; from that of the second, two drams forty grains; of the third, two drams thirty grains: the indissoluble earthy matter amounted in each of the experiments to three drams.

The spirituous extracts made from all the sorts were stronger than the watry; that of the canister sort was notably pungent on the tongue; of the Dutch, only bitterish, without any acrimony; the spirituous extract of ours tasted somewhat pungent, but the watry only bitter. The spirituous extracts of all the sorts are of a fine green colour, the watry of a yellowish brown. The distilled waters and spirits have no taste or smell. Bohn, however, pretends that the distilled water, especially if drawn from the juice of the herb, will occasion vomiting if taken to the quantity of an ounce or two.

**TOPAZ.** See **PRECIOUS STONES**, No. 4.

**TOPHI.** Duckstein of the Germans, Pori. Kirwan says that these differ from the calcareous stalactites, not only in shape, but principally in this, that they have been formed by a gradual deposition of earths, chiefly of the calcareous kind, barely diffused through water itself, and not in air. Hence they are of a soft and porous texture, and of the same colour as the stalactites.

The word tophi is also used as synonymous with tufa or traafs, which is a volcanic product. Great heaps of tufa, or tophi, are found in Italy, forming various hills, and covering large tracts of land, from whence it is cut and carried for making the walls, vaults, and upper ceilings of houses; it is a very soft kind of stone, extremely advantageous for these purposes, on account of its small weight, and being easily cut into any form. The inhabitants of Umbria and other parts of Italy, dig with very little labour various subterraneous corridors and large excavations under earth, where they keep wines and many provisions quite free from the irregularities and excesses of temperature.

**TORREFACTION.** This name is given to a kind of calcination by which ores are deprived of the volatile mineralising substances, the sulphur and arsenic which they contain. It is also applied to signify the roasting of some pharmaceutical preparations. Thus, for instance, we say torrefied rhubarb, &c.

**TORSTEN.** An iron ore of a bright blueish black, or yellowish gray colour, and fibrous texture, shews a red trace when scratched, and is weakly magnetic before calcination. According to Rinman, it is less dephlogisticated than haematites.

**TOUCHSTONE.** The black basalt is used for examining the precious metals by the touch, and is commonly distinguished by this name. See **ASSAY**.

**TOURMALIN.** See **PRECIOUS STONES**, No. 11.

**TRAASS.** See **TARRAS**.

**TRAGACANTH GUM.** See **GUMS**.

**TRANSMUTATION.** See **METALS**.

**TRAPP.** A dark gray or black stone, generally invested with a ferruginous crust, and crystallized in opaque triangular or polyangular columns, is called basalt; that which is irregular, or breaks in large thick square pieces, is called trapp, from its resemblance to stairs, of which trap is the Swedish name. Their constituent principles and relation to acids and fluxes are exactly the same. The texture of this stone is either coarse, rough, and distinct, or fine and indiscernible. This latter sort is often reddish; it is always opaque, and moulders by exposure to the air; some specimens give fire with steel very difficultly, though it is always very compact; sometimes it is sprinkled over with a few minute shining particles: its specific gravity is 3,000.

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When heated red hot, and quenched in water, it becomes by degrees of a reddish brown colour; it melts per se in a strong heat into a compact slag. Borax also dissolves it in fusion, but mineral alkali not entirely.

**TRIP.** See **TRIPOLI**.

**TRIPOLI EARTH.** See **ROTTEN STONE**.

**TRITORIUM.** A vessel generally made of glass, used for the separation of liquors of different densities, as oil and water. Its largest diameter is the middle, and it terminates with an aperture at each of the two extremities. The lower extremity, the aperture of which is very narrow, is dipped into the mixed liquor; and when it is sufficiently filled, the upper orifice is to be stopped close, by pressing the thumb upon it, by which means the liquor contained will not run out at the lower aperture when the vessel is raised from the mixed liquor. When the fluids, of which this liquor consists, have perfectly separated according to their respective densities, by removing the thumb the heavier fluid will run out at the lower extremity, and the separation will be thus effected.

**TRITURATION** is an operation which consists in the mechanical division of bodies, and is executed by the same methods, and by the same instruments that are employed for other divisions of this kind; that is to say, in mortars, upon porphyries, and in mills. This word is generally applied to denote the grinding of several bodies together, to unite them with each other; as for instance, the extinction of mercury in the operation of ethiops mineral, and others of a similar kind.

**TROMPE.** The trompe, or blowing machine, is formed of a hollow tree which rests upon a cask whose lower head is knocked out, and the open part of the cask itself plunged to a certain depth under water. A current of water is made to fall through this wooden trunk upon a stone which is erected in the middle of the cask. The air becomes disengaged, and is obliged to pass out at a collateral aperture in the cask, by means of a tube which carries it to the lower part of the furnace. This air is afforded, 1. by that air which the water carries along with it: 2. by a current which passes through apertures made at the distance of six feet from the summit of the tree, and called trompilles. I use the French names, because I do not know of any appropriated English terms.

The dimensions of a good trompe, according to Chaptal, are the following:

Length of the tree or wooden trunk, from its summit to the side apertures or trompilles, six feet.

Length of the tree from the trompilles to the cask, eight feet.

Height of the cask, five feet.

Diameter of the cask, four feet six inches.

The form of the internal part of the trunk, above the trompilles, is that of a funnel, whose superior opening is eighteen inches, and its inferior diameter five.

The diameter of the cavity of the tree, below the trompilles, is eighteen inches.

The diameter of the trompilles is six inches.

Dr. Lewis, in his Philosophical Commerce of Arts, treats expressly on this simple and useful instrument, on which he made many experiments. The following remarks, references, and investigations, are abridged from his work.

The earliest method of animating the large fires of the furnaces for smelting ores, appears to have been by exposing them to the wind. Such was the practice of the Peruvians before the arrival of the Spaniards in that country. Alonso Barba relates, that their furnaces, called guairas, were built on eminences, where the air was freest;

that

that they were perforated on all sides with holes, through which the air was driven in when the wind blew, which was the only time the work could be carried on; that under each hole was made a projection of the stone work on the outside, and that on these projections were laid burning coals to heat the air before its entrance into the furnace. Some authors speak of several thousands of these guairas burning at once on the sides and tops of the hills of Porosi.

It is said that several remains of a like rude process are to be seen in some parts of our own country. The old blomery hearths, as they are called, for the running down of iron ore, are all on the tops of hills; a situation which can scarcely be supposed to have been chosen on any other account than for the conveniency of the wind, being in other respects extremely incommodious.

The gradual succession of bellows to this insufficient mode of supplying air, cannot perhaps be traced. It appears, that at some of our iron furnaces, and others, the bellows were formerly moved by a handle, as those of the smith's forge, or by the pressure of the foot upon a treadle, or by other means requiring the strength of men; and that since the force of water has been called in aid to move them, the quantity of ore run down has not only been far greater, but the separation of the metal more complete.

The first account that is to be met with of a machine for propelling air into furnaces, by a fall of water carrying down air with it, is of one at the copper or brass furnaces at Tivoli, near Rome\*. In this machine a square wooden pipe of considerable width, and open at both ends, is placed upright. A stream of water runs in at the top, and is discharged at the bottom; and about the middle of the height of the pipe a smaller horizontal one is inserted, which reaches to the furnace, and is said to convey to it a strong blast of air.

According to M. Belidor†, a pipe with air holes, inserted into an air vessel, is used for this purpose in some parts of France.

M. Mariotte‡ gives an account of a contrivance for blowing fire by a fall of water, which consists of a funnel and pipe, without air holes, inserted into an air vessel.

Mr. Stirling|| describes a machine erected in Scotland, for blowing air into the furnaces in which lead ores are smelted, and for conveying fresh air into the works. This machine consists of a funnel and pipe, with air holes, inserted into an air vessel.

The blowing machines used in Dauphiny for the forges and smelting furnaces, have a great resemblance in their general structure to the foregoing.

In the county of Foix, the blowing machines, as described by Reaumur§, are considerably different from the foregoing. The pipe is rectangular, and the part above the choak divides into three funnel-shaped partitions. On the top is a reservoir or cistern of water; and two of the partitions, close on all sides, pass up above the surface of the water, for carrying down air, and thus supplying the place of the lateral air holes: the water enters into the third partition, which is only the space between the two foregoing, and which has but two sides, formed by the two opposite sides of the others.

Mr. Barthes¶ gives a minute description of a blowing machine at the forge

\* See the third number of the Philosophical Transactions, and the Journal des Savans for 1666.

† In his *Architecture Hydraulique*. ‡ In his *Traité du Mouvement des Eaux*. || In No. 576 of the Philosophical Transactions for the year 1745. § In the *Art des Forges*. ¶ Vol. iii. of the *Memoirs of the Correspondents of the French Academy*.



of St. Pierre, on the river Obriou. Its general structure is nearly the same with that of Foix, but the height of water above the choak much less.

Dr. Lewis's trials, though not carried to such a length as he could have wished, satisfied him and those who assisted at them, that much more air is to be obtained by dividing the stream by means of a cullender, than by any other methods that have been tried; and that with such a machine as that of St. Pierre above described, a stream of a hundred and fifty gallons at most in a minute is sufficient to produce a continued blast from a pipe of three quarters of an inch bore, of such strength as to support a column of water of three feet or more.

His summary view of the most material particulars which his experiments have discovered, with regard to the perfection of the structure of blowing machines, and his description from them of such a machine as promises to be the most effectual, are as follow:

The bottom of the reservoir of the water should be about fourteen feet above the level of the ground: we need not be very solicitous about procuring a greater height; for though a greater would be of some advantage, yet this advantage appears to be much less considerable than has been commonly imagined. In the channel by which the water is conveyed, are to be placed gratings of different sizes; and before the aperture a finer grating, which may be either a perforated iron plate or a wire sieve, to serve as strainers for keeping back such matters as would obstruct the apertures which the water is afterwards to pass through. The stream should enter at one side, or be so managed, that the water in the reservoir or funnel may not be agitated by it, or put into a spiral motion, which Dr. Lewis's experiments shewed to be very injurious.

In the bottom of the reservoir is to be made a round hole, for admitting the upper end of a cylindrical pipe of copper or cast iron, five or six inches in the bore, and seven feet long. To the end of this pipe is to be fitted a cullender about a foot long, with the holes triangular, of half an inch each side, and six or seven spaces from top to bottom, at equal distances, must be left without holes, for admitting air to pass down to the lower streams. All the holes should be directed downwards, that the streams may not be forcibly projected against the sides of the pipe which is to receive them, so as to have their velocity too much diminished.

If there are six of the perforated spaces in the cullender, the number of holes in each may be twenty; so that the whole number will be one hundred and twenty. The side of each of the triangular holes being half an inch, the area of each will be the eighth part of a square inch, and the sum of their areas will be fifteen square inches. The quantity of water running through one aperture of such an area, at the depth of seven feet and a half under the surface, comes out on calculation about six hundred and twenty-two gallons in a minute; but the real quantity will doubtless be much less than this, on account of the great friction of the water in passing through a number of small holes, and of the resistance of the air, which increases in a very high ratio according to the increase of the velocity and enlargement of the surface: it is in part to make up for these retardations, that the pipe is directed to be made so high. The surface of the water is here above thirteen times greater than if it passed all through one circular aperture.

Both the pipe and the cullender should have a flanch or rim round their orifices, and be secured to one another by screws passing through the rims of both, with a plate of lead between them to make the juncture tight, as commonly practised

practised in joining iron pipes for water works. This way of joining them admits the cullender to be taken off and cleaned, when a diminution of the effect of the machine shews the holes to be choaked up; which, however, it is apprehended, will seldom if ever happen.

As the holes will permit more water to run through than may at all times be wanted, it is proper to have some contrivance for occasionally closing a part of them. This may be effected by means of a thin copper pipe, open at both ends, as high as the cullender, and of such width as just to drop into it. It will be easily conceived, that when this register is let entirely down, the lateral holes will be covered, and the water admitted only to those in the bottom; and that by raising it further and further, more and more of the lateral holes will be uncovered. The register is to be hung by a wire to a cross-bar over the reservoir, by which it may be raised or lowered; and a scale or divided board may be adjusted against the upper part of the wire, for shewing the height of the register, or the number of holes closed by it.

The most commodious and effectual way of admitting air to the water appears to be that of hanging the throat of the funnel, in this case the cullender, within the wider receiving pipe; for by this means the air is admitted freely and uniformly all round. This last pipe should likewise be of iron or copper, twelve inches in diameter, and spread out at top to the width of sixteen or eighteen inches, that a large space may be left round the cullender: this space should reach three or four inches above the uppermost perforations of the cullender, to prevent any of the water from being dashed over the top.

A pit is to be sunk in the ground, not less than six feet deep. In this is to be placed an air vessel, made of wood lined with lead, without a bottom, three or four feet in width, and ten or eleven high. The vessel should be supported on feet of a proper strength, with sufficient spaces between them for the water to pass freely out: this way is preferable to the common one of placing the lower edge of the vessel on the bottom of the pit, and cutting an aperture in the side, because the height of the aperture is so much taken off from that of the vessel. The reservoir being fourteen feet above the ground, and the upper pipe and cullender reaching down eight feet, only six feet remain below the cullender; so that the air vessel having six feet sunk, the ground will reach nearly up to the cullender, and almost the whole height of the undermost pipe will be included within the vessel. This pipe may be above nine feet long, three feet or more of it going down into the pit; which three feet are here an entire gain in the height of the fall, for the pipe in the other machines comes at most no lower than the level of the ground where the water runs off on the outside. This height is gained in virtue of the compressed air in the vessel pushing down the water below: it may be always as great as the height to which the water is intended to rise in the gage. At the distance of five or six inches under the orifice of the pipe is to be placed the concave iron plate or stone for the water to fall on. In the top of the air vessel is to be fixed the gage and the blowing pipe.

Such is the general construction of the blowing machine, which (says Dr. Lewis) promises to be particularly useful in cases where water is scarce, or where the want of a natural fall renders it necessary to raise, by very expensive means, the great quantities requisite for working the common bellows. Dr. Lewis thinks too, that one of these machines will be sufficient for the iron forge, and for sundry other purposes where the quantity of air is not required to be very great; that it will be less expensive, on account of the durability of its materials and the



simplicity of its structure, than any kind of bellows now in use; and what is of principal importance, that much less water will serve for working it. He adds, in cases where one of the machines cannot supply air enough, as for the large iron smelting furnace, two pipes may be used, both fed by one reservoir, and entering into one air vessel. The using of two pipes appears more eligible than enlarging the bore of one; for air cannot be so freely introduced into a large body of water, though divided into streams by the cullender, as into two smaller ones of equal quantity.

It may be observed, that the blast will be stronger in a dense state of the atmosphere than when it is more rare or expanded, a greater quantity of air being then introduced under an equal volume. If therefore the quantity of water has been adjusted so as to raise the gage to a proper height when the air was light, it will frequently happen that the same quantity of water shall raise it higher, and consequently, if no greater height is required, that a part of the water may be saved. As the gage of the machine discovers by inspection the variations in its effect, the register affords convenient means of regulating its power, and increasing or diminishing the quantity of water.

The method of blowing in our large furnaces is by iron bellows or machines, worked by a steam engine. Some years ago I had a conversation on this subject with one of our most eminent iron masters, whose name I should be glad to mention as a credit to myself, if I had at this time an opportunity of asking his permission.

The air machines are iron cylinders six feet in diameter, in which a piston works with a stroke of seven feet in length. Each stroke therefore protrudes 198 cubic feet of air. At best the rate of working is sixteen strokes in a minute. The density of the air is such that it will raise three pounds weight on a square inch hole in the piston, in which effect the stroke has some part. For the pressure in the reservoir is less, being about two pounds on the same surface. The reservoir, called the regulating belly, is a large close chamber open below, and surrounded with a sufficient mass of water to rise within it, and by its reaction keep up the density of the air with which its upper part is supplied from the cylinder. The difference of height between the surfaces of the water within and without the reservoir is between six and seven feet, and the rise and fall at each stroke of the piston is about four or five inches on the outer surface. I think he afterwards said two or three. From this last datum we may deduce the size of the regulating belly or its horizontal section. For its surface will be to that of the piston, inversely as this rise is to the length of the stroke. If the medium of the first numbers be taken, its surface will be 19 times that of the piston, which is  $28\frac{1}{2}$  square feet, that is to say, 536 square feet, or a square whose side is 23 feet. But if the medium of the second numbers be taken, the surface will be 45 times that of the piston, that is 1271 square feet, or a square whose side is about  $36\frac{1}{2}$  feet. The larger this surface, the steadier the blast. From the regulating belly proceeds the nozzle or twyer (tuyere) as it is called. Its diameter at the aperture is one, two, or three inches. They have sometimes enlarged them for experiment as far as five; but they then found the apparatus not to supply the air quickly enough, or at least not with the same advantage as when a smaller aperture was used.

If we attend to the height of the water on the outside of the reservoir, we shall find the force of this apparatus to be greatly beyond that of the other bellows in use. Six or seven feet of water upon the base of a square inch will give 72 or 84

solid inches, and those at 1000 ounces to the cubic foot, or 1728 inches will give 41 ounces, or two pounds nine ounces for the pressure upon a square inch, represented by the first of these numbers. The second number will give near 48 ounces, or three pounds. These pressures referred to a column of mercury, which is a very usual and convenient method of admeasurement, will correspond to 5.3 and 6.2 inches elevation of that fluid; that is to say, at most not one fifth of an atmosphere.

In some of the early volumes of the Abridgment of the Transactions, there is an account of a method of conveying air to vast distances, through pipes for the purpose of blowing, and as I think, speaking from recollection, for the communication of mechanic effect. This scheme was put in practice by the father of the iron master from whom the preceding information was received. The project, which did not succeed, cost four thousand pounds. Three engines were erected, consisting of bellows worked by large water wheels, at a fall of water eighteen hundred yards distant from the iron work to which the air was intended to be conveyed. A pipe ten inches diameter conveyed the air from the engine to the works, and the stream of air was never so strong as to blow out a candle. So I find it in my notes; but I think, from recollection, the expression was, to affect the flame of a candle, and certainly a very gentle breath of air was meant. The engine worked but a few strokes before it stopped. The proprietor concluded that the pipe was in some part designedly obstructed; but upon advice, he put a cat into the pipe, which walked through it and came out at the other end. It remained, therefore, to ascertain whether the obstruction of the air arose merely from the length of the pipe. For this purpose holes were cut in the pipe at various distances from the end at which the air entered, and proper coverings prepared; that each might be opened at pleasure. It was found that the engine worked slower, the remoter the hole which was opened, the wind issuing of course with less strength; and when the hole was made at a certain distance, it stopped. I did not ask the distance. It is said that the passage of air from a blowing machine to its place of escape is considerably impeded through pipes of the length of 40 or 50 feet. The fact, which is perfectly authentic, is certainly very curious. Whether it is to be ascribed to the loss by friction of a momentum, in which the velocity is so great and the mass so small; or whether there be any effect similar to that stickage which takes place when wool, or other elastic bodies are rammed into a tube, must be determined from a numerical estimate of all the facts, and may perhaps require new experiments. I cannot help, however, entertaining the opinion, that the former cause is the most effectual in this business, and that the undertaking here described might have been made to answer by enlarging the diameter of the tube. For if the impediment be friction arising from the velocity of the mass, that element will diminish in proportion as the diameter of the tube is increased, and the quantity of surface rubbed against by the same mass of air will not alter. Hence, it should follow, that if a tube, of an inch diameter and three feet long, do not perceptibly resist the passage of the air, another tube thirty feet long, will afford no more resistance, provided its diameter be ten inches, that is to say, proportional to its length.

TUFA. See TOPHI.

TUNGSTEN is a mineral of an opaque white colour, very heavy, and of a moderate degree of hardness: its crystals are octahedrons. Its specific gravity is 6.0665, according to Briffon; from 4.99 to 5.8, according to Kirwan.

This substance has a sparry appearance, and was long confounded with the



white tin ore. It is found at Bitsberg, at Riddharhittan, at Marienberg, at Altemberg in Saxony, and at Sauberg near Ehrenfriedersdorff.

Mr. Raspe, in Crell's Annals for June 1785, gave an account of two mines of tungsten in the province of Cornwall, from which thousands of tons might be extracted. This philosopher obtained the metal in the proportion of about thirty-six livres the quintal. He adds that this metal contains little iron; that it is very fixed and refractory in the fire; and that it acts on glass like the hardest steel.

The tungsten was formerly classed among iron ores; but it has been examined by Scheele, Bergman, and De Luyart. See ACID OF TUNGSTEN.

**TURBITH MINERAL.** This name is given to a preparation of mercury made in the following manner:

Some mercury is put into a glass retort, and upon it is poured an equal weight of concentrated vitriolic acid, or more, according to the degree of concentration of this acid. These matters are to be distilled together in a sand-bath till nothing remains in the retort but a dry saline substance, which is a combination of mercury with vitriolic acid. The union of these two matters cannot be directly effected but by this process, because the vitriolic acid cannot attack mercury unless it be highly concentrated, and because this concentration cannot be performed so well in open as in close vessels. Besides, the heat in this operation favours considerably the action of the acid upon the mercury. The acid which passes into the receiver during the distillation is very sulphureous, from the loss of vital air, which may be expelled again by heat from the mercurial calx.

The white saline mass left at the bottom of the retort is to be put into a large vessel, and upon it large quantities of hot water are to be poured at several different times. This water separates the redundant acid, takes it from the mercury, which is then precipitated to the bottom of the vessel, in form of a very shining yellow citron-coloured powder. This yellow mercurial powder, having been well washed, is called turbith mineral, and is a very powerful emetic.

The water with which it is washed contains a portion of acid that was united with the mercury; and also contains a little mercury in the saline state, which is soluble in water, by means of the very large quantity of acid.

Turbith mineral may also be made by precipitating mercury from its solution in nitrous acid, by means of vitriolic acid, or of some vitriolic salt. For this purpose the nitrous acid must be well saturated with mercury; for if it contain any unsaturated acid, no turbith mineral will appear upon adding either vitriolic salts or pure vitriolic acid. Hence mistakes may be committed in making experiments to discover the presence of vitriolic acid, by means of a solution of mercury, as is frequently done.

Turbith mineral becomes yellow only by being deprived of the adhering vitriolic acid, and remains white till it has been washed with a large quantity of water; in general, the more perfectly it is deprived of acid, the deeper yellow colour it acquires.

Turbith mineral has been formerly celebrated for the cure of the venereal disease; but it is now little used, because preferable mercurial remedies have been discovered. See ACID (VITRIOLIC), and MERCURY.

**TURNSOLE.** See HELIOTROPISM.

**TURKEY STONE.** Cos Turcica. This stone is of a dull white colour, and often of an uneven texture, some parts appearing more compact than others, so that it is in some measure shattery. It is used as a whetstone: and those of the finest grain are the best hones for the most delicate cutting tools, and even for razors.

razors, lancets, &c. Its specific gravity is 2,598. It gives fire with steel, yet effervesces with acids. Kirwan found that 100 parts of it contain 25 of mild calcareous earth, and no iron.

There probably are two sorts of stones known by this name, as Wallerius affirms that which he describes neither to give fire with steel, nor effervesce with acids. Workmen affirm that this stone hardens with oil. The value of such specimens as contain a very fine grit, or siliceous part, is much greater than that of the common samples. Artists select them by trial; but it is not generally known that most of these stones have a fine and a coarse side, and ought therefore to be sawed with an attention to this circumstance. It naturally arises from the stone having been formed from subsidence in water.

**TURMERIC** (*terra merita*) *curcuma longa*, is a root brought to us from the East Indies. Berthollet had an opportunity of examining some turmeric which came from Tobago, which was superior to that which is met with in commerce, both in the size of the roots and the abundance of the colouring particles. This substance is very rich in colour, and there is no other which gives a yellow colour of such brightness; but it possesses no durability, nor can mordants give it a sufficient degree. Common salt and sal ammoniac are those which fix the colour best, but they render it deeper, and make it incline to brown; some recommend a small quantity of muriatic acid. The root must be reduced to powder to be fit for use. It is sometimes employed to give the yellows made with weld a gold cast, and to give an orange tinge to scarlet; but the shade the turmeric imparts soon disappears in the air.

Mr. Gohlische gives two processes for fixing the colour of turmeric on silk. The first consists in aluming in the cold for twelve hours a pound of silk in a solution of two ounces of alum, and dyeing it hot, but without boiling, in a bath composed of two ounces of turmeric and a quart (measure) of aceto-citric acid (see page 234), mixed with three quarts of water. The second process consists in extracting the colouring particles from the turmeric by aceto-citric acid, in the way described for brazil wood, and in dyeing the silk alumed as already mentioned in this liquor, either cold or only moderately warm. The colour is rendered more durable by this than by the former process. The first parcel immersed acquires a gold yellow; the colour of the second and third parcels is lighter, but of the same kind; that of the fourth is a straw colour. Mr. Gohlische employs the same process to extract fine and durable colours from fustic, broom, and French berries; he prepares the wool by a slight aluming, to which he adds a little muriatic acid. He seems to content himself in these cases with vinegar or some other vegetable acid, instead of his aceto-citric acid, for the extraction of the colour; he directs that a very small quantity of solution of tin should be put into the dye-bath.

**TURPENTINE** is a resinous juice extracted from several trees. Sixteen ounces of Venice turpentine being distilled with water, yielded four ounces and three drams of essential oil; and the same quantity, distilled without water, yielded with the heat of a water-bath two ounces only. When turpentine is distilled or boiled with water till it becomes solid, it appears yellowish; when the process is further continued, it acquires a reddish brown colour. In the first state it is called boiled turpentine; and in the second colophony, or common rosin. On distilling sixteen ounces in a retort with an open fire increased by degrees, Neumann obtained, first, four ounces of a limpid colourless oil; then two ounces and a dram



of a dark brownish red empyreumatic oil, of the consistence of a balsam, and commonly distinguished by that name.

The essential oil commonly called spirit of turpentine, cannot without singular difficulty be dissolved in spirit of wine, though turpentine itself is easily soluble in that spirit. One part of the oil may be dissolved in seven parts of rectified spirit of wine; but on standing a while, the greatest part of the oil separates and falls to the bottom.

**TURPETH.** See **TURBITH.**

**TUTENAG.** This name is given in India to the semi-metal zinc. It is sometimes applied to denote a white metallic compound brought from China, called also Chinese copper, the art of making which is not known in Europe. It is very tough, strong, malleable, may be easily cast, hammered, and polished; and the better kinds of it, when well manufactured, are very white, and not more disposed to tarnish than silver is. Three ingredients of this compound may be discovered by analysis; namely, copper, zinc, and iron.

The above is a note of Keir upon Macquer. Some of the Chinese white copper is said to be merely copper and arsenic.

Mr. Engestrom, in the Memoirs of Stockholm for the year 1775, quoted by Kirwan, has given us an analysis of a tutenag ore from China. It was of a white colour, interspersed with red streaks of calx of iron, and so brittle as to be easily broken betwixt the fingers. In the dry way it exhibited the same appearances as zinc spar, except that it lost no part of its weight. It was soluble in the mineral acids, particularly with the assistance of heat, and with the vitriolic afforded vitriol both of zinc and iron. The quantity of fixed air was so small as to be absorbed by solution. It contained in various specimens from 60 to 90 per cent. of zinc; the remainder was iron, and a small proportion of clay. This variety of calciform ores, which was mixed with a notable proportion of iron, was also discovered in Germany by Mr. Bindheim, who found it to consist of zinc, a little iron, and silex. 4 Berl. Schrift. 400.

**TUTTY.** A metallic substance, various in its composition and properties, which nevertheless appear to depend on the presence of zinc. The better sorts of tutty, according to Neumann, are in semi-cylindrical concave pieces, like the bark of a tree; ponderous and somewhat sonorous; moderately compact, and generally not easy to break; of an ash or mouse-gray colour, often with yellow or green variegations; pretty smooth on the inside, full of cavities or protuberances on the outside. The entire, compact, gray pieces are preferred; the broken, powdery, crumbly, yellow, or reddish, rejected. Boecler relates that tutty has a sharp taste, but no such taste is perceptible in ours.

Wiegleb affirms that the matter which in the fusion of brass is deposited over the melted metal is called tutty; but Neumann made various unsuccessful enquiries relative to its origin, and the place where it may be produced. That it is not produced at Goslar, or Schneeberg, nor at any of the considerable foundries of brass, bronze, bell-metal, &c. in Germany, Holland, France, Italy, and England, he affirms from his own experience. He therefore concludes that it is an artificial production, expressly made up of the calx of zinc, with clay and other matters.

**TYPE METAL.** The basis of type metal for printers is lead, and the principal article used in communicating hardness is the regulus of antimony, to which copper and brass in various proportions are added. The properties of a good type metal

metal are, that it should run freely into the mould, and possess hardness without being excessively brittle. The smaller letters are made of a harder composition than those of a larger size. It does not appear that our type foundries are in possession of a good composition for this purpose. The principal defect of their composition appears to be, that the metals do not uniformly unite. In a piece of casting performed at one of our principal foundries, the thickness of which was two inches, I found one side hard and brittle when scraped, and the other side, consisting of nearly half the piece, was soft like lead. The transition from soft to hard was sudden, not gradual. If a parcel of letter of the same size and casting be examined, some of them are brittle and hard, and resist the knife, but others may be bended and cut into shavings. It may easily be imagined that the duration and neatness of these types must considerably vary. I have been informed, but do not know the fact from trial, that the types cast in Scotland are harder and more uniform in their qualities.

## V

### V A P

**VAPOUR.** The elastic fluids or subtle invisible matters which fly off from bodies subjected to chemical operations or otherwise, are called vapours. But accurate chemical writers confine this appellation to such exhalations only as may be condensed into the fluid state by cold, in contradistinction to the aerial fluids, of which scarcely any are so convertible by any means in our power.

**VARNISH.** Lac varnishes or lacquers consist of different resins in a state of solution, of which the most common are mastic, sandarach, lac, benzoin, copal, amber, and asphaltus. The menstrua are either expressed or essential oils, as also spirit of wine. For a lac varnish of the first kind, the common painter's varnish is to be united by gently boiling it with some more mastic or colophony, and then diluted again with a little more oil of turpentine. The latter addition promotes both the glossy appearance and drying of the varnish. Of this sort is the amber varnish. To make this varnish, half a pound of amber is kept over a gentle fire in a covered iron pot, in the lid of which there is a small hole, till it is observed to become soft, and to be melted together into one mass. As soon as this is perceived, the vessel is taken from off the fire, and suffered to cool a little; when a pound of good painter's varnish is added to it, and the whole suffered to boil up again over the fire, keeping it continually stirring. After this, it is again removed from the fire; and when it is become somewhat cool, a pound of oil of turpentine is to be gradually mixed with it. Should the varnish, when it is cool, happen to be yet too thick, it may be attenuated with more oil of turpentine. This varnish has always a dark-brown colour, because the amber is previously half-burned in this operation; but if it be

required



required of a bright colour, amber powder must be dissolved in transparent painter's varnish, in Papin's machine by a gentle fire. As an instance of the second sort of lac varnishes with ethereal oils alone, may be adduced the varnish made with oil of turpentine. For making this, mastich alone is dissolved in oil of turpentine by a very gentle digesting heat in close glass vessels. A varnish of the consistence of thin turpentine is obtained for aerostatic machines, by the digestion of one part of elastic gum cut into small pieces, in thirty-two parts of rectified oil of turpentine. Previously to its being used however it must be passed through a linen cloth, in order that the undissolved parts may be left behind. The third sort of lac varnishes consists in the spirit of wine-varnish. The most solid resins yield the most durable varnishes; but a varnish must never be expected to be harder than the resin naturally is of which it is made. Hence, it is the height of absurdity to suppose that there are any incombustible varnishes, since there is no such thing as an incombustible resin. But the most solid resins by themselves produce brittle varnishes; therefore something of a softer substance must always be mixed with them, whereby this brittleness is diminished. For this purpose gum elemi, turpentine, or balsam of capaiva are employed in proper proportions. For the solution of these bodies the strongest alcohol ought to be used, which may very properly indeed be distilled over alkali, but must not have stood upon alkali. The utmost simplicity in composition with respect to the number of the ingredients in a formula is the result of the greatest skill in the art; hence, it is no wonder that the greatest part of the formulas and recipes that we meet with are composed without any principle at all.

In conformity to these rules, a fine colourless varnish may be obtained, by dissolving eight ounces of gum sandarach and two of Venice turpentine in thirty-two ounces of alcohol by a gentle heat. The following, which is obtained from five ounces of shell lac and one of turpentine, dissolved in thirty-two ounces of alcohol by a very gentle heat, is harder, but of a reddish cast. To these the solutions of copal and amber are undoubtedly preferable in many respects. The solution of the former is effected by triturating an ounce of powder of gum copal, which has been well dried by a gentle heat, with a dram of camphire, and, while these are mixing together, adding by degrees four ounces of the strongest alcohol, without any digestion. But Wiegleb, from whom the foregoing is extracted, confesses, that he never could succeed in this way with amber.

Between this and the gold varnish there is only this difference, that some substances that communicate a yellow tinge are to be added to the latter. The most ancient description of two sorts of it, one of which was prepared with oil, and the other with spirit of wine, is to be found in Alexius Pedemontanus De i Secreti, Lucca, of which the first edition was published in the year 1557. But it is better prepared, and more durable, when made after the following prescription: Take two ounces of shell lac, of annatto and turmeric of each one ounce, and thirty grains of fine dragon's-blood, and make an extract with twenty ounces of alcohol in a gentle heat.

Oil varnishes are commonly mixed immediately with the colours, but lac or lacquer varnishes are laid on by themselves upon a burnished coloured ground: when they are intended to be laid upon naked wood, a ground should be first given them of strong size, either alone or with some earthy colour, mixed up with it by levigation. The gold lacquer is simply rubbed over brass, tin, or silver, to give them a gold colour.

Pere d'Incarville has informed us, that the tree which affords the varnish  
of

of China is called Tsi-chou by the Chinese. This tree is propagated by offsets. When the cultivator is desirous of planting it, he takes a branch, which he wraps up in a mass of earth, by means of flax. Care is taken to moisten this earth; the branch pushes out roots, and is then pruned and transplanted. This tree grows to the size of a man's leg.

The varnish is drawn in spring. If it be a cultivated tree, it affords three gatherings. It is extracted by incisions made in the spring; and when the varnish, which is received in shells, does not flow, several hogs bristles moistened with water or saliva are introduced into the wound, and cause it to run. When the tree is exhausted, the upper part of it is wrapped in straw, which is set on fire, and causes the varnish to precipitate to the bottom of the tree, where it flows out of perforations made for that purpose.

Those who collect the varnish set out before day-break, and place their shells beneath the apertures. The shells are not left longer than three hours in their place, because the heat of the sun would evaporate the varnish.

The varnish emits a smell which the workmen are very careful to avoid respiring. It produces an effect which they call the bud of the varnish.

When the varnish issues from the tree, it resembles pitch. By exposure to the air, it gradually becomes coloured, and is at last of a beautiful black.

The juice which flows from incisions made in the trunk and branches of the thus toxicodendron, possesses the same properties. The tree that grows in the French climates affords a white milky fluid, which becomes black and thick by the contact of the air; its colour is the most beautiful black, and it would be easy to introduce this valuable species of industry into the kingdom, because the tree grows wonderfully well in all climates, and resists the cold of the winter.

To make the varnish bright, it is evaporated by the sun; and a body is given to it with hog's gall and martial vitriol.

The Chinese use the oil of tea, which they render drying by boiling it with orpiment, realgar, and arsenic.

The fundamental facts in the art of varnishing by resins are reduced by Chaptal to the following principles.

To varnish any substance, consists in applying upon its surface a covering of such a nature, as shall defend it from the influence of the air, and give it a shining appearance.

A coat of varnish ought therefore to possess the following properties:—1. It must exclude the action of the air; because wood and metals are varnished to defend them from decay and rust. 2. It must resist water; for otherwise the effect of the varnish could not be permanent. 3. It ought not to alter such colours as are intended to be preserved by this means.

It is necessary therefore that a varnish should be easily extended or spread over the surface, without leaving pores or cavities; that it should not crack or scale; and that it should resist water. Now resins are the only bodies that possess these properties.

Resins consequently must be used as the bases of varnish. The question which of course presents itself must be then, how to dispose them for this use; and for this purpose they must be dissolved, as minutely divided as possible, and combined in such a manner, that the imperfections of those which might be disposed to scale, may be corrected by others.

Resins may be dissolved by three agents—1. By fixed oil. 2. By volatile oil.



oil. 3. By alcohol. And accordingly we have three kinds of varnish: the fat or oily varnish, essential varnish, and spirit varnish.

Before a resin is dissolved in a fixed oil, it is necessary to render the oil drying. For this purpose the oil is boiled with metallic calces, in which operation the mucilage of the oil combines with the metal, while the oil itself unites with the vital air of the calx. To accelerate the drying of this varnish, it is necessary to add oil of turpentine.

The essential varnishes consist of a solution of resin in oil of turpentine. The varnish being applied, the essential oil flies off, and leaves the resin. This is used only for paintings.

When resins are dissolved in alcohol, the varnish dries very speedily, and is subject to crack; but this fault is corrected by adding a small quantity of turpentine to the mixture, which renders it brighter, and less brittle when dry.

The coloured resins or gums, such as gum gutta, dragon's blood, &c. are used to colour varnishes.

To give lustre to the varnish after it is laid on, it is rubbed with pounded pumice stone and water; which being dried with a cloth, the work is afterwards rubbed with an oiled rag and tripoli. The surface is last of all cleaned with soft linen cloths, cleared of all greasiness with powder of starch, and rubbed bright with the palm of the hand.

**VEGETABLE KINGDOM.** In the mineral kingdom little of chemical operation takes place, wherein the peculiar locality or disposition of the principles which act upon each other appears to have any considerable effect. The principles for the most part simple act upon each other by virtue of their respective attractions; if heat be developed, it is for the most part speedily conducted away; if elastic products be extricated, they in general make their escape;—in a word, we seldom perceive in the operations in the mineral kingdom any arrangement which at all resembles the artificial dispositions of the chemist. But in the animal and vegetable kingdoms it is far otherwise. In the former of these, bodies are regularly changed by mechanical division, by digestion, and the application of peculiar solvents, in a temperature exceeding that of the atmosphere, and the whole of the effects are assisted, modified and kept up by an apparatus for admitting the air of the atmosphere. The subjects of the vegetable kingdom possess undoubtedly a structure less elaborate. They exhibit much less of those energies which are said to be spontaneous. The form of their vessels is much simpler, and, as far as we can perceive, their action is obedient to the changes of the atmosphere in quality and moisture, the mechanical action of winds, the temperature of the weather, and the influence of light. In these organized beings, the chemist discovers principles of a more compounded nature than any which can be obtained from the mineral kingdom. These do not previously exist in the earth, and must therefore be results of vegetable life.

The most obvious difference between vegetables and animals is, that the latter are in general capable of conveying themselves from place to place; whereas vegetables, being fixed in the same place, absorb by means of their roots and leaves such support as is within their reach. This appears on the whole to consist of air and water. The greatest part of the support of animals are the products already elaborated in the vegetable kingdom. The products of these two kingdoms in the hands of the chemist are remarkably different, though perhaps not exclusively so. One of the most distinctive characters seems to be the presence

sence of phlogisticated air or azotic gas, which may be extricated from animal substances by the application of nitrous acid, and enters into the composition of the volatile alkali afforded by destructive distillation. It was long supposed, that volatile alkali was exclusively the product of the animal kingdom, but it is now well known that certain plants likewise afford it.

When it is considered, that by far the greater part of every organized substance is capable of assuming the elastic form, and being volatilized by heat; that the products are during life brought into combination by slow and long-continued processes, and are kept separate from each other in the vessels of the plant or animal; that these combinations are liable to be altered by the destruction of those vessels, as well as by every notable change of temperature, it will not appear surprising that the chemical analysis of plants should be in a very imperfect state. The ancient chemists had no other methods of examining plants than by destructive distillation, and the successive application of water and ardent spirit. They had no method of examining the elastic products of their distillations. This method is on every account of little value. For the new combinations produced by the heat, exhibit products nearly similar from substances originally very different. The other method by the application of solvents is somewhat more accurate, and has besides afforded products of considerable utility in the arts and for the ordinary purposes of life. A slight sketch of the requisite manipulations has been given under our article ANIMAL KINGDOM.

In the structure of vegetables we observe the external covering or bark, the ligneous or woody matter, the vessels or tubes, and certain glandular or knotty parts. The comparative anatomy, and immediate uses of these parts, form an object of interesting research, but less immediately within the province of a chemical work.

The nutrition or support of plants appears to require water, earth, light, and air. There are various experiments which have been instituted to shew that water is the only aliment which the root draws from the earth. Van Helmont planted a willow, weighing fifty pounds, in a certain quantity of earth covered with sheet lead: he watered it for five years with distilled water; and at the end of that time the tree weighed one hundred and sixty-nine pounds three ounces, and the earth in which it had vegetated was found to have suffered a loss of no more than three ounces. Boyle repeated the same experiment upon a plant, which at the end of two years weighed fourteen pounds more, without the earth in which it had vegetated having lost any perceptible portion of its weight.

Messrs. Duhamel and Bonnet supported plants with moss, and fed them with mere water; they observed that the vegetation was of the most vigorous kind; and the naturalist of Geneva observes, that the flowers were more odoriferous, and the fruit of a higher flavour. Care was taken to change the supports before they could suffer any alteration. Mr. Tillet has likewise raised plants, more especially of the gramineous kind, in a similar manner; with this difference only, that his supports were pounded glass, or quartz in powder. Hales has observed that a plant which weighed three pounds, gained three ounces after a heavy dew. Do we not every day observe hyacinths and other bulbous plants, as well as gramineous plants, raised in saucers or bottles containing mere water?

All plants do not demand the same quantity of water; and nature has varied the organs of the several individuals conformably to the necessity of their being supplied with this food. Plants which transpire little, such as the mosses and the lichens, have no need of a considerable quantity of this fluid; and accordingly



they are fixed upon dry rocks, and have scarcely any roots; but plants which require a larger quantity, have roots which extend to a great distance, and absorb humidity throughout their whole surface.

The leaves of plants have likewise the property of absorbing water, and of extracting from the atmosphere the same principle which the root draws from the earth. But plants which live in the water, and as it were swim in the element which serves them for food, have no need of roots; they receive the fluid at all their pores; and we accordingly find that the fucus, the ulva, &c. have no roots whatever. The purer the water, the more salutary it is to plants. Mr. DuRoi has drawn this consequence from a series of well-made experiments, by which he has proved that water impregnated with salts is fatal to vegetation. Hales caused them to absorb various fluids by making incisions in their roots, and plunging them into spirits of wine, mercury, and various saline solutions; but he was convinced that these were all poisons to the vegetables. Besides, if these salts were favourable to the plants, they would be again found in the individual which had been watered with a solution of them; whereas Messrs. Thouvenel and Cornette have proved that these salts do not pass into the vegetable. We must nevertheless except the marine plants, because the sea-salt of which they have need is decomposed in them; and produces a principle which appears necessary to their existence, since they languish without it.

Though it is proved that pure water is more proper for vegetation than water charged with salts, it must not on that account be concluded, that water cannot be disposed in a more favourable manner to the development of vegetables, by charging it with the remains of vegetable and animal decomposition. If, for example, the water be loaded with principles disengaged by fermentation or putrefaction, the plant then receives juices already assimilated to its nature, and these prepared aliments must hasten its growth. Independent of those juices already formed, the nitrogene gas, which constitutes one of the nutritive principles of plants, and is abundantly afforded by the alteration of vegetables and animals, must facilitate their development. A plant supported by the remains of vegetables and animals, is in the same situation as an animal fed on milk only; its organs have less difficulty in elaborating this drink than that which has not yet been animalized.

The dung, which is mixed with earths, and decomposed, not only affords the alimentary principles we have spoken of, but likewise favours the growth of the plant by that constant and steady heat which its ulterior decomposition produces. Thus it is that Fabroni affirms his having observed the development of leaves and flowers in that part of a tree only which was in the vicinity of a heap of dung.

From the preceding circumstances it appears, that the influence of the earth in vegetation is almost totally confined to the conveyance of water, and probably the elastic products from putrefying substances to the plant. See ARABLE LANDS, and EARTH VEGETABLE.

Vegetables cannot live without air. From the experiments of Priestley, Ingenhousz, and Senebier, it is ascertained that plants absorb the azotic part of the atmosphere; and this principle appears to be the cause of the fertility which arises from the use of putrefying matters in the form of manure. The aerial acid or fixed air is likewise absorbed by vegetables, when its quantity is small. If the composition of fixed air be charcoal and vital air, as Mr. Lavoisier has endeavoured to prove (see AIR FIXED), a large quantity must by some means enter into

into the structure of vegetables. Chaptal has observed that fixed air predominates in the fungus and other subterraneous plants. But by causing these vegetables, together with the body upon which they were fixed, to pass, by imperceptible gradations, from an almost absolute darkness into the light, the acid very nearly disappeared; the vegetable fibres being proportionally increased, at the same time that the resin and colouring principles were developed, which he ascribes to the vital air of the same acid. Senebier has observed that the plants which he watered with water impregnated with fixed air, transpired an extraordinary quantity of vital air, which likewise indicates a decomposition of the aerial acid.

Light is almost absolutely necessary to plants. In the dark they grow pale, languish, and die. The tendency of plants towards the light is remarkably seen in such vegetation as is effected in a chamber or place where the light is admitted on one side; for the plant never fails to grow in that direction. Whether the matter of light be condensed into the substance of plants, or whether it act merely as a stimulus or agent, without which the other requisite chemical processes cannot be effected, is uncertain. It is ascertained that the processes in plants serve, like those in animals, to produce a more equable temperature, which is for the most part above that of the atmosphere. Dr. Hunter, quoted by Chaptal, observed by keeping a thermometer plunged in a hole made in a sound tree, that it constantly indicated a temperature several degrees above that of the atmosphere, when it was below the fifty-sixth division of Fahrenheit; whereas the vegetable heat, in hotter weather, was always several degrees below that of the atmosphere. The same philosopher has likewise observed, that the sap which, out of the tree, would freeze at 32°, did not freeze in the tree unless the cold were augmented 15° more.

The vegetable heat may increase or diminish by several causes, of the nature of disease; and it may even become perceptible to the touch in very cold weather, according to Buffon.

The compound principles obtained from vegetables are, 1. mucilage, 2. oil, 3. resin, 4. fecula, 5. vegetable gluten, 6. sugar, 7. acid, 8. alkali, 9. colouring matter, 10. pollen or wax, 11. wood, 12. mixed fluids distinguished by the name of sap, and 13. elastic fluids.

Mucilage appears to be the first state of the alimentary juices in vegetables. It composes the basis of most seeds and young plants, and greatly resembles the mucilage of animals, and like that is most abundant in young subjects. It is sometimes found entirely alone, as in mallows, linseed, &c. sometimes it is combined with matters insoluble in water, which it keeps suspended in the form of an emulsion. In other instances it is combined with oil. Not unfrequently with sugar, as in the sugar cane, Indian wheat, carrot, &c. It is also confounded with the essential salts with excess of acid, as in sorrel, tamarinds, and the like. The characters of mucilage are insipidity of taste, solubility in water, insolubility in ardent spirit, coagulation by the action of weak acids, the emission of a considerable quantity of fixed air, at the same time that it becomes converted into coal without exhibiting any flame. Lastly, it is capable of passing to the acid fermentation when diluted with water.

The formation of mucilage appears scarcely to demand the action of light, but its subsequent changes require the presence of that agent. Dried mucilage is known in commerce by the name of gum, which see.

Oils are of two kinds, the fat or fixed oils, and the volatile or essential oils. See OIL.

Camphor



Camphor may be referred to the essential oils, though in various particulars it differs from them remarkably. See the article.

A variety of resins are used in the arts; for which see **RESIN**, **BALSAMS**, and **GUM RESIN**, also **GUM ELASTIC**.

Chaptal considers the fecula of vegetables as a substance in no other respect differing from mucilage than by its insolubility in cold water. He accordingly considers the paste or combination of flower with hot water as an absolute mucilage. To these inductions various objections might be made; but as the facts lead us at present not much beyond conjecture, it is the less necessary to discuss the matter. For the general properties of this substance see **BREAD**, and **GLUTEN VEGETABLE**. It is one of the first articles of food for the greater number of animals.

For the properties of sugar, see **SUGAR**, and **ACID OF SUGAR**.

Many vegetables contain so large a proportion of acid, that its presence is exhibited to the taste and by other marks of disengaged acidity. These impure acids have been arranged according to various divisions. They may be distinguished either according to their distinctive characters, or the means by which they are obtained; and the latter, on account of our imperfect knowledge of the constitutional parts of the products of organized bodies, appears on the whole to be the most useful. Morveau in the *Encyclopedie* reckons two classes, namely, 1. such acids as exist ready formed in the vegetable, whether in a state partly disengaged, as in sour fruits, or disguised by some neutralizing principle, as the acid of benzoin, and other balsams, and the half-saturated acids of tartar and sorrel: 2. acids produced by chemical change in the constitution of the vegetable matter, whether by the acetous fermentation, or by abstraction of the nitrous acid from saccharine or oily matters; or lastly by destructive distillation.

The native vegetable acids are almost always more or less contaminated with mucilaginous and other matter. These acids may in some instances be purified by straining the juice carefully, inspissating it either by heat or by freezing, and suffering the acid to crystallize. This process, however, though the most simple and natural, is far from being easy, or in many instances practicable. The acids of tartar and of sorrel crystallize in this way, but nevertheless with a portion of the vegetable alkali in combination. Later very ingenious processes have been adopted by combining the acid with calcareous earth or some other suitable basis, then washing off the mucilaginous fluid, and again disengaging the acid by some other acid more strongly attractive of the base. Instances of these processes may be seen under the article **ACID OF CITRONS**. But I cannot avoid making an observation in this place, to express my doubt whether it be the true vegetable acid in its original state, which is extricated at this second decomposition. For we find that many acids are disposed to alter their character by entering into combination. Thus in corrosive sublimate and other compounds, the marine acid at the time of changing its state of combination assumes the dephlogisticated or aerated state. When to the aerated marine acid is added the vegetable alkali, the first compound assumes a large proportion of the vital air superadded to the acid, and forms a neutral salt containing an acid very highly aerated, while the remaining addition of alkali forms the common muriated vegetable alkali. So likewise the acids obtained from crystals of verdigris, or from foliated tartar, are not common vinegar, but the same acid in the aerated state, called radical vinegar. It is probable that the vinegar assumed the vital air at the time of its entering into these combinations,

combinations, and it is well known that it cannot dissolve copper unless it be enabled to attract this principle.

The vegetable acids produced by fermentation are all comprehended under the denomination of vinegar. The several kinds of vinegar are found to differ from each other merely in strength, and the greater or less abundance of foreign mucilaginous matter. See VINEGAR.

The abstraction of nitrous acid by distillation from sulphur, phosphorus, and other combustible matters, for the purpose of communicating to them the portion of vital air which is requisite to produce the acid state, has been with great success applied to vegetable and animal products by Scheele, Bergman, Berthollet, and other eminent chemists. See ACID OF SUGAR. When sugar or other saccharine substances are acidified by repeated distillations of nitrous acid from them, the acid of tartar is formed; if the process be continued farther, this acid becomes converted into acid of sugar; a farther continuation produces vinegar. Several chemists who maintain the doctrine of phlogiston, are of opinion, that the nitrous acid contributes nothing to these acids, but merely develops them from superabundant oils and earthy matters. But when we reflect on the acidification of sulphur and phosphorus by this very treatment, which requires nothing but the addition of vital air, as far as we can perceive, to convert them into acids; it seems reasonable also to infer, that vegetable matters are acidified in the same way, and that the differences of the acids do not consist in a greater or less purification of the basis, but in the proportion of vital air communicated to each.

Lemery in the Memoirs of the Royal Academy at Paris for 1721, quoted by Keir in his valuable Chemical Dictionary, article ACIDS VEGETABLE, gives a number of observations on the distilled acids from plants. He observes that all plants contain acid, but that the quantity is not to be estimated by the product yielded by distillation; because it rises from some plants in combination with volatile alkali, or with oil. Thus even sorrel, which is known to contain much acid, yields when it is distilled also much volatile alkali, which combines with the acid, so that a less quantity of acid is in this case extricated than from plants which exhibit less indications of acidity. But if instead of distilling sorrel or its juice in an open fire, either of these be first exposed to the gentle heat of a water bath, the volatile alkali will be thus expelled, and the acid may be afterwards obtained much more copiously by applying a stronger heat, than if this latter degree of heat, which would have raised both principles at once, had been applied at first. Or again, if the sorrel be macerated and suffered to ferment in water, the volatile salt will fly off, and the quantity of clear acid product by subsequent distillation will be proportionally increased. Many plants yield scarcely any acid by distillation, without a previous maceration and fermentation. Others again, as lemons, give little if any signs of volatile salt, and much disengaged acid. He divides plants relatively to this subject into four classes. 1. Those which give acid from the beginning to the end of the distillation, with little or no volatile salt. Such are rennet apples, and the pears called Martin sec, or Franc royal. The second class contains plants which yield more or less volatile salt, but not till the end of the distillation, whereas the disengaged acid appears chiefly at first. Among this class are the cichorium intybus Linn. celery, lettuce, fumitory, gentian-root, violets, peaches, roses, polypody, rape-seed, melons, artichoke-bottoms, chestnuts, apricots, red currants, elderberries, and grape stones. The third class gives the volatile salt not only at the end but likewise at the beginning of the distillation, when the acid also sometimes

is.



is expelled, and continues to distil till near the end, and then the volatile salt again appears. Of this class are common white succory, *carduus benedictus*, red beets, spinach, cherries, onions, sage, parsley, and many others. The fourth class gives much more volatile salt than the third, and this is distributed more uniformly and plentifully in all the different periods of the distillation. The acid also appears more or less in every period, but at last is quite overpowered and concealed by the quantity of volatile salt. Of this class are the leaves and stalks of the *atriplex hortensis*, *lamium album*, *parietaria*, artichoke leaves, seeds of the wild gourd, wheat, barley, oats, and many others.

There are even some plants which give no traces of acidity in distillation; yet, as Lemery remarks, we must not thence infer that they contain none. For these plants yield a great deal of a volatile salt in which the acid is combined and hid. The same plants, previously fermented, yield acid in distillation.

The age of plants, and the difference of the parts of the same plant, affect the quantity of acid obtainable by distillation. Thus, in analysing lettuce, he remarked, that younger plants give less acid than old ones, that the leaves give less acid than the stalks or roots, and that the juice yields less than the fibrous parts remaining after this juice had been expressed.

Every observation yet made on the acids obtained from organized substances by distillation, tends to shew that they are different from acids obtained by other means from the same substances. Little has been done to ascertain the differences between these acids, but it is not probable on the whole that they possess any immediate identical principle or basis. The alteration effected by the heat, exclusive of the empyreuma arising from burned oil, appears to be of the same nature as that effected by the nitrous acid, namely, a more perfect acidification. Keir, from whose dictionary I have extracted much of the present article, thinks that the action of fire decomposes the native acids, and approximates, or perfectly converts them to vinegar; in which respect fire and the nitrous acid are similar in their operation upon vegetable acids, all which by the continued abstraction of the nitrous acid are changed into the acetous acid. An experiment of Mr. Westrumb\*, who well understands this new branch of chemistry, relative to the examination of vegetable acids, proves in one instance this conversion of a native acid into the acetous, and gives probability to its generality. He analysed a plant of the diadelphical class used for pasture, and from two pounds of the fresh herb, he procured twenty ounces of an empyreumatic acid liquor, which he afterwards rectified, and divided into two equal portions. On beginning to saturate one of these portions with alkali, he observed that a white precipitate fell, which was a true tartar. He then completed the saturation, and evaporated, by which he obtained  $5\frac{1}{2}$  drams of a deliquescent salt, which being mixed with vitriolic acid and manganese and distilled, yielded three drams of pure vinegar. This experiment shewed that the native acid of the plant is the acid of tartar, a small part of which had been raised by the force of the heat unaltered, while the greater part of the acid is decomposed by the fire, and changed into vinegar.

The same author is disposed to consider the acids produced from the animal and vegetable kingdoms, as not essentially distinct. He remarks that the acids of ants, of milk, and of sugar of milk, as well as the acid of amber, which is directly of mineral, though probably originally of vegetable origin, yield the same principles as vegetable acids when analysed, and therefore may all be com-

\* Westrumb. Abhandlungen, band 2. heft. 1. s. 350.

prehended under one general class of acids of organic bodies. In this class he remarks, we ought certainly not to omit the permanently elastic fluid acid, called calcareous gas, or fixed air, being that to which all the other acids of this class are principally resolved by analysis. Lastly the nitrous acid, generally ranked among the mineral acids, being actually produced from putrefied animal and vegetable substances, and the phosphoric acid, are entitled by their origin, though not by their analysis, to the same class of acids of organic bodies.

The following acids then compose this general class of organic acids :

Acid, acetous.	Acids distilled from honey, from plants,
Acid of amber.	from tartar, from sugar, and from
Acids of ants, silk-worms, and other insects.	woods.
Acid of apples.	Acid of fat.
Acid of benzoin.	Acid of galls.
Acid gas, called calcareous gas, or fixed air.	Acid of milk.
Acid of camphor.	Acid, nitrous.
Acid of citrons.	Acid, phosphoric.
Acid of corks.	Acid, tartareous.
	Acid, saccharine or oxaline.
	Acid of sugar of milk.

The German chemists have paid particular attention to the conversion of the acids of organic bodies into each other by such management as the present state of chemistry admits. Mr. Keir has collected in an alphabetic order, the principal facts relating to those vegetable substances which have been examined with a view of investigating their acids. At the same time that I copy in this place his excellent abridgment, the reader is informed that he will obtain much valuable information by recurring to the original.

Agave Americana, Linn. Mr. Hoffman of Weimar has examined a juice which sweats from the calix of this plant, in order to know whether it was similar in its contents to the juices of our indigenous plants, and he found that it contained the acids of tartar and of apples.

Aloes. Scheele obtained from an extract of aloes, by means of the nitrous acid, the acids of sugar and of apples.

Apples. Scheele discovered in the juice of this fruit a new acid, to which he gave the name of acid of apples. See that article. By means of nitrous acid, Hermstadt obtained from this juice acid of tartar †.

Bilberry. The juice of this fruit contains acid of apples, not mixed with any acid of citrons, according to Scheele. Hermstadt says that it contains acid of tartar, and a peculiar acid, by which he means Scheele's acid of apples; and that when treated with nitrous acid, it yielded acid of sugar. But Hoffman's experiments confirm Scheele's conclusion, that this fruit contains no other native acid than that of apples. By treating this acid with spirit of wine and manganese, he obtained an ether.

Bilberry (*Vaccinium myrtillus*). This fruit contains, according to Scheele, equal parts of acids of citrons and of apples.

Bramble (*Rubus chamaemorus*). The fruit contains acids of citrons and of apples, in nearly equal quantities, according to Scheele.

\* Crell, *Annal.* 1788, st. 1. p. 51.

† Hermstadt über die Natur der Grundsäure des Pflanzenreichs, § 22.



Camphor. By treating this substance with nitrous acid, Mr. Kofegarten\* has effected a decomposition, and obtained a peculiar acid substance. He distilled a mixture of one part of camphor and twelve parts of dephlogisticated nitrous acid. Along with the red nitrous vapours an oil passed into the receiver, and much of the camphor was sublimed. By repeating the operation eight times, the camphor was at last quite decomposed, and silver white crystals of the form of parallelopipedons were produced. These crystals were soluble in two hundred times their quantity of water, but unsoluble in spirit of wine; they exhaled a smell similar to that of saffron; impressed on the tongue a sour bitter taste; reddened blue vegetable juices; neutralized alkalis, and therewith formed very soluble salts; dissolved magnesia, iron, copper, zinc, bismuth, arsenic, cobalt, manganese, and corroded tin and lead. They formed no precipitate when added to solutions of martial vitriol, or of calcareous earth in marine acid; but they precipitated a yellow salt from a solution of mercury in nitrous acid. From these properties it is evident that this salt was not the saccharine acid.

Cherry. Scheele found that the juice of cherries contained about equal parts of acids of citrons and of apples. Hermbstadt says that he discovered acid of tartar in this juice†: but Westrumb, having repeated this examination, did not find any acid of tartar, but only acid of citrons; a part of which was disengaged, another part was combined with calcareous earth, and another with fixed alkali‡. In Crell's Annal. for 1786, he says he found also acid of apples; but in his Treatise, published in 1787, he makes no mention of this acid. By means of nitrous acid, both Hermbstadt and Westrumb obtained acid of sugar.

Citrons. Scheele has discovered in the juice of lemons, as well as in many other vegetable matters, an acid possessed of peculiar properties, called by him acid of citrons. See that article.

Coffee. The infusion of roasted coffee, evaporated to the consistence of a syrup, and treated with nitrous acid, gave the two acids of sugar and of apples||.

Coloquintida. Scheele did not obtain any saccharine acid by treating this matter with nitrous acid.

Corks. Mr. Brugnatelli § has obtained a yellow acid by treating cork with repeated abstractions of nitrous acid. This acid of corks unites with all alkalis and earths, forms with them neutralized salts, of which some are crystallizable, but are nevertheless apt in some degree to deliquesce. With fixed vegetable alkali it combines into a dark yellow mass, which crystallizes in the cold in the form of small needle-like prisms, soluble in water, vitriolic, nitrous, or marine acids, but unsoluble in vinegar or spirit of wine. This acid of corks has, like the saccharine acid, a strong affinity to calcareous earth, which it separates from lime water, and forms a grayish saline powder, unsoluble not only in water, but also in the acid of corks, although it dissolves in marine acid. Lastly, this acid of corks acts upon several metals, and exhibits different appearances, which according to Mr. Brugnatelli deserve a more particular examination.

Cranberry (*Vaccinium oxycoccos*). This fruit, according to Scheele, contains acid of citrons alone.

Currants, red and white. Their juice gave the acid of citrons and of apples

\* De Camphora, Auctore D. A. J. F. Kofegarten, Goetting. 1785.

† Hermbstadt, l. c. § 15.

‡ Westrumb, Versuche mit Pflanzen-saure, § 10. Abhandlung, band ii. heft 1.

§ Scheele, loc. cit.

¶ Crell, Annal. 1787, ft. 2. s. 145.

upon examination by Westrumb\*. Hermbstadt says that they contain acid of tartar, but Westrumb's experiments seem to be sufficiently decisive to the contrary.

Elder-berries. The fruit of the black elder was found by Scheele to contain scarcely any acid but that of apples.

Galls. A peculiar acid has been obtained from galls by Scheele. See ACID OF GALLS.

It is probable that from other astringent vegetable matters, especially those used in dyeing, acids might be obtained similar to the acid of galls. Mr. Morveau has extracted a resin from galls, which he supposes is the acidifiable basis, which, together with pure air, forms the acid of galls. This acid, when purified, is said to make a fine and durable ink. See INK.

Geranium acidum. Cartheuser† has procured small acid crystals from the juice of this plant. According to Hermbstadt, this acid is the saccharine; for he says that the acid is different from the common acid of tartar, as the compound which it forms with calcareous earth, and which is very unsoluble, cannot be decomposed by vitriolic acid; and further, that the crystals of this acid are similar to the acid of sorrel. For by adding to a solution of these crystals a solution of ponderous earth in vinegar, he obtained a precipitate, which, being digested with vitriolic acid, gave the saccharine acid, and vitriolated ponderous earth.

Gooseberry. Scheele found in this fruit the acid of apples alone. Hermbstadt indeed says that the acid of tartar is contained in the juice of gooseberries; but at the same time he admits, that it cannot be exhibited by the usual process of saturating with chalk, and subsequent separation by vitriolic acid; but that in order to procure acid of tartar from this juice, it is necessary previously to treat it with nitrous acid. But this latter acid is known to decompose vegetable juices, and to alter the modification of vegetable acids, so that not only the acid of tartar may be obtained by the action of nitrous acid from the juice of gooseberries, but, by the further operation of the nitrous acid, the acid of gooseberries may be changed into the acid of sugar, as Hermbstadt found. It does not then seem probable that the acid of tartar exists as such in the unaltered juice of this fruit.

Grapes. The juice of grapes, with or without the assistance of fermentation, has been found to deposit tartar, and consequently to contain the acid of tartar united with fixed alkali.

Grass-roots. Hermbstadt‡ expressed the juice of the roots of grass (*tritium repens*), and obtained by evaporation and clarification a sweetish extract, which being kept three months yielded saline crystals, soluble in water, and capable of giving an earthy precipitate when decomposed by an alkali. Upon abstracting nitrous acid from this salt, and adding to it a solution of calcareous earth in vinegar, a precipitate fell, which was found on examination to consist of the acid of tartar saturated with lime. Hermbstadt seems to consider this experiment as shewing the existence of acid of tartar in grass-roots: but it seems rather to prove that this acid does not exist as such there, until the action of the nitrous acid had developed it; for it is evident that the native crystals formed in the concentrated and clarified juice were not a tartareous salt of lime, being easily soluble in water.

Gums. Gum arabic, treated by Scheele with nitrous acid, yielded acids of sugar and of apples.

\* Loc. cit. § 6.

† Cartheuser, Samml. ft. 6. f. 423.

‡ Loc. cit. § 23.



Gum tragacanth, during its solution in nitrous acid, let fall a white powder, which on examination was found to be the acid of the sugar of milk. The solution also yielded the acids of apples and of sugar\*.

Haw (*Cratægas aria*). This fruit was found by Scheele to contain nearly equal parts of acid of apples and citrons.

Honey, like sugar, yields by distillation an acid liquor, and, by treatment with nitrous acid, the acid of sugar.

The distilled acid of honey has been said to be capable of dissolving gold; but this solution has not occurred to modern chemists. Perhaps it may dissolve the precipitate of gold. Neither is it known to have any effect on silver, platinum, or mercury. It dissolves lead, and forms crystals with it. It attacks copper, which renders it green. It dissolves tin and iron, with which latter metal it crystallizes. Mr. de Morveau has determined its affinities in the following order: Fixed vegetable alkali, fixed mineral alkali, ponderous earth, lime, magnesia, volatile alkali, earth of alum, metallic calces, water, alcohol.

Lemons. See Citrons.

*Leontodon taraxacum*. The expressed juice of the roots of this plant, treated with nitrous acid, gave indications of the presence of the acid of tartar.

Manna, by treatment with nitrous acid, yielded acid of apples, and of sugar†.

Mulberries. The juice of this plant contains, according to Hermbstadt, the acid of tartar in a native state. For, having clarified this juice and saturated it with chalk, he obtained a precipitate, which by adding vitriolic acid gave the acid of tar disengaged. Angelus Sala obtained from this juice, by evaporation and crystallization, a crystallizable acid salt, which probably may have been a tartar‡.

Oil of olives. By repeatedly and copiously abstracting nitrous acid from this oil, Westrumb obtained a salt which sublimed and crystallized.

Peruvian bark. An extract of this bark, treated with nitrous acid, yielded both the acids of apples and of sugar.

*Prunus spinosa*, et *domestica*. The fruit of these trees gave acid of apples, and little or no acid of citrons.

*Prunus padus*. This fruit gave acid of citrons, and little, if any, acid of apples§.

Poppy. The juice of poppies treated with nitrous acid gave acids of sugar and of apples.

Raspberries. The juice of this fruit gave the acids of citrons and of apples nearly in equal quantities, according to Scheele. But Hermbstadt says, that by saturating this juice with chalk, and then separating the earthy basis from the compound by means of vitriolic acid, he obtained acid of tartar.

Rhapontic. From the expressed acid juice of the root of the rheum rhaponticum, Mr. Bindheim has extracted the acid of tartar, which in this juice seems partly in a disengaged state and partly combined with calcareous earth and with calx of iron. By treating this juice with nitrous acid, he obtained the acid of sugar.

Rhubarb. The infusion of this root being treated with the nitrous acid, gave the acids of sugar and of apples. In this root, the acid of sugar exists in

\* Scheele.

† Scheele.

‡ Oper. Angel. Salæ, p. 135.

§ Crell, Chem. Anr. 1784, b. i. f. 229.

§ Hermbstadt, ib. § 21.

a native state, and the addition of nitrous acid is not essential to its production. For Scheele has shewn, that if a pound of Indian rhubarb be infused in hot water, a powder subsides, which by washing becomes white, in weight about 1½ oz. that this powder is actually a saline compound, consisting of calcareous earth saturated with the oxaline acid, and is not a vitriolic selenite, as Model had affirmed.

*Rhibes cynosbati*. The fruit, according to Scheele, contains the acid of citrons, with little or no acid of apples.

*Salap*. The root of *salap* treated with nitrous acid by Scheele, yielded the acids of sugar and of apples.

*Service* (*Sorbus aucuparia*). The fruit of this tree was found by Scheele to contain acid of apples with little or no acid of citrons.

*Solanum dulcamara*. The fruit of this plant was found by Scheele to contain acid of citrons.

*Sorrel* (*Rumex acetosa*). The expressed juice of the leaves of sorrel, by evaporation yielded crystals of tartar; and by saturating this juice with chalk, and separating the earth by means of vitriolic acid, an acid of tartar was obtained in a crystallized form. But although Hermbstadt discovered no other acid in the juice of this plant than that of tartar, it is nevertheless frequently used, as well as the *oxalis acetosella*, for preparing the salt sold under the name of native salt of wood-sorrel, the proper acid of which is the oxaline or saccharine.

*Wood-sorrel* (*Oxalis acetosella*). The acid contained in this plant is described under the article ACID OF SORREL.

*Strawberry*. The juice of strawberries was found by Scheele to contain equal parts of the acids of apples and citrons.

*Sugar*. See Acid of Sugar.

*Sugar of Milk*. See Acid of Sugar of Milk.

*Sumach* (*Rhus coriaria*). Professor Tromsdorf\* extracted from the berries of sumach a crystallizable acid salt, and determined some of its properties. His son has fully examined this salt, and has ascertained it to be a true tartar†.

*Tamarinds*. Angelus Sala‡ and Baumé|| have each of them, by lixiviating the fruit of tamarinds, evaporation and crystallization, obtained an acid salt. This acid has been further examined by Scheele, Retzius, Hermbstadt, Kehler and Westrumb. Scheele thought he perceived the presence of his citron acid in this fruit; but the four latter authors affirm, that the acid is that of tartar. Westrumb particularly, who has written last on the subject, has given a very copious examination of this fruit, and seems to have ascertained, that it contains the acid of tartar, also tartar itself, together with a mucilaginous and a saccharine matter§.

*Vaccinium vitis idæa*. The fruit of this plant contains the citron acid, according to Scheele.

*Wood*. It is well known that an acid liquor is obtained by distilling wood. Boe have has obtained acids from those of box, guyac, juniper, and oak.

Mr. Goettling¶ has examined the acid distilled from the bark of the birch. By letting it remain at rest during three months, he was able to separate much of

\* Aët. Acad. Elect. Mogunt. Erfurt, 1780. † Crell, Annal. 1787. st. 5. f. 419.

‡ Oper. p. 134. § Elem. de Pharmacie, Paris 1762.

§ Einige Versuche mit Pflanzensauren, abh. ii. 1. 229.

¶ Crell's Journal Chem. 1779.



the oil that was mixed with it; and by saturating it with fixed alkali, he obtained a dark-coloured neutral salt, which he purified by fusion, and by solution, and a subsequent evaporation. Upon distilling this purified neutral salt with vitriolic acid, he obtained an acid no longer empyreumatic, but possessed of an alliaceous smell. The academicians of Dijon have observed the results in distilling beech-wood. From 55 ounces of dry shavings they got 17 ounces of a rectified acid, which, when freed from oil of an amber colour, was of the specific gravity, comparatively with that of water, as 49 to 48, and of such a strength, that one ounce of this acid required for its saturation  $23\frac{1}{2}$  ounces of lime-water.

According to these chemists, the affinities of the acids of wood are in the following order: Lime, ponderous earth, vegetable fixed alkali, mineral fixed alkali, magnesia, volatile alkali, calces of zinc, manganese, iron, lead, tin, cobalt, copper, nickel, arsenic, bismuth, mercury, antimony, silver, gold, platina, and earth of alum.

By digesting beech-wood in nitrous acid, and by distilling the mixture, Hermbstadt obtained a residuum which was found to contain acid of tartar. Goettling obtained acid of sugar by treating wood with nitrous acid.

Much light has been thrown on the constitution of the vegetable acids by the conversions effected in Scheele's method of applying the nitrous acid. This subject has been very successfully cultivated by Hermbstadt and Westrumb, several of whose discoveries are contemporary, though unknown to each other. For the following extensive and perspicuous enumeration of facts, I am indebted to the dictionary of Keir.

1. The acid juice of lemons saturated with the absorbent earth, called crabs-eyes, and preserved in a bottle slightly stopped, with the addition of a little spirit of wine, gradually acquires the properties of vinegar, as Stahl has observed.

2. The acids of tartar and of milk digested, with the addition of water and some spirit of wine, during some weeks, were each of them converted into vinegar\*. Crell remarks, that fixed and phlogisticated airs were at the same time extricated.

Hermbstadt succeeded in the conversion of the acid of tartar into the acetous without the addition of spirit of wine. He dissolved four ounces of acid of tartar in sixteen ounces of water, and kept this solution in a vessel covered with paper in a warm place, during a summer. In three months the taste of this solution was changed, and the air in the upper part of the vessel was found to be fixed. In six months the liquor had the taste of vinegar, and by distillation yielded good vinegar. In the residuum a salt was observed, which was not acid of tartar, nor altogether saccharine acid; although he remarks that in another instance, where the acid of tartar is united with a fixed alkali, and exposed to fermentation, the saccharine acid is obtained. For a salt consisting of the saccharine acid and fixed alkali is found in casks containing French-wine-vinegar, and is sold as salt of wood-forrel, to which it is equivalent in its component parts, and in the proportion of these parts.

3. Eight parts of spirit of wine, eight parts of water, and one part of acid of tartar, mixed and digested during three months, with a very gentle heat, gave vinegar†.

\* Bergman, Opusc. iii. 364.

† Westrumb über die Natur der Zuckerlaure, &c. I. 5.

4. Another experiment similar to the last mentioned, except that the saccharine acid was used instead of the tartareous, succeeded also in the production of vinegar\*.

5. The acid of tartar distilled with vitriolic acid, gave an acid like the acetous. But vinegar was more perfectly produced, when to the mixture of tartareous and concentrated vitriolic acids some manganese was added successively, until this addition no longer altered the colour of the liquor; which circumstance indicated the dephlogistication of the acid of tartar, and the production of vinegar. During this operation much fixed air was produced†.

6. Three parts of saccharine acid, two parts of manganese, and twelve parts of nitrous acid, gave by distillation vinegar, and some gas or air‡.

7. By abstracting nitrous acid from saccharine acid, a part of the latter acid was converted into vinegar; and this is the reason, as Hermbstadt remarks, why, in the operation for preparing acid of sugar, sometimes only a small quantity is produced of the saccharine acid, the remainder being changed into the acetous||.

8. A mixture of two parts saccharine acid, four parts manganese, and three parts vitriolic acid, being distilled, yielded vinegar§.

9. Upon distilling the acid of sugar, with six times its quantity of vitriolic acid, vinegar, phlogisticated vitriolic acid, and fixed air, were found in the receiver, and pure vitriolic acid in the retort¶.

10. Acid of tartar is converted into acid of sugar, by treatment with nitrous acid, and by further dephlogistication into vinegar.

11. One part of the acid of tartar,  $1\frac{1}{2}$  part of manganese, and six parts of nitrous acid, gave by distillation vinegar and nitrous gas.

12. By distilling a mixture of two parts of acid of tartar, four parts of manganese, and three parts of concentrated vitriolic acid, vinegar was produced, and much fixed air was expelled.

13. By applying dephlogisticated marine acid to the acids of tartar or sugar, in the same manner as Westrumb had applied the nitrous acid, Hermbstadt obtained vinegar.

14. The acid of citrons was converted into the saccharine by Westrumb, in the usual manner of abstracting nitrous acid\*\*. Scheele had tried this without success, and gave, among the peculiar properties of this acid, that of not being convertible into the saccharine acid. Westrumb thinks that Scheele had used too much nitrous acid, and had thereby changed the acid of citrons into vinegar.

15. Scheele converted the acid of apples into the saccharine acid, by means of nitrous acid.

16. Hermbstadt and Westrumb have changed into the acids of tartar, sugar, or vinegar, the native acids of tamarinds, and many other fruits, &c. by means of nitrous acid.

17. Sugar, when treated with weak nitrous acid, gave acid of tartar, and with stronger nitrous acid, yielded acid of sugar.

18. Bergman treated spirit of wine repeatedly with nitrous acid, and observed indications of saccharine acid. Westrumb by the same means obtained perfectly crystallized acid of sugar; and when the dephlogistication was continued further, the acetous acid was produced.

\* Westrumb über die Natur der Zuckerfaure, &c. † Ibid. ‡ Westrumb. Ibid. || Hermbstadt, Grundsaure des Pflanzenreichs, &c. f. 37, 38, 39. § Hermb. Ibid. f. 41. ¶ Westrumb. loc. cit.  
\*\* Crell, Annal. 1786, b. ii. f. 242.



19. Spirit of wine distilled with vitriolic acid and manganese yields, according to Hermbstadt, vinegar.

20. By saturating the residuum in the preparation of dulcified spirit of nitre, with chalk, an insoluble salt was formed, which being digested with vitriolic acid yielded a disengaged acid of tartar.

21. Scheele discovered some acid of apples in the process of preparing the saccharine acid from sugar, by means of nitrous acid.

22. Hermbstadt has procured vinegar from spirit of wine, without the assistance of acids, by means of caustic fixed alkali. He digested six ounces of caustic fixed alkali in two pounds of strong spirit of wine, during two days, in a gentle heat, by which the spirit of wine acquired a dark brown colour. By distillation he obtained 1 pound 9 ounces of spirit, and he repeated the abstraction several times, till the spirit was consumed. The retort contained now a dark brown fluid, which was very caustic in taste, and smelt of soap. Having diluted this liquor with water, filtrated the mixture through powdered glass, and evaporated it to dryness, he re-dissolved it in water, added more vitriolic acid than was merely sufficient for the saturation of the alkali, and distilled the mixture to dryness. The distilled liquor was of a peculiar smell and taste, was free from vitriolic acid, and had a great resemblance to the acetous acid, but was not completely vinegar. He saturated this acid liquor with fixed alkali, evaporated the salt to dryness, and digested it with spirit of wine, in order to separate the acetous salts from any other, the former being soluble in spirit of wine. Accordingly he obtained an insoluble residuum, which being put on hot coals, smelt like burnt tartar; and by abstracting the spirit of wine, he got 4 ounces of a neutral salt, which had been dissolved in the spirit, and which was found to be composed of acetous acid and fixed alkali; for upon adding to it vitriolic acid, and distilling the mixture, he obtained a true vinegar.

Although so many instances have been given of the conversion of the acid of sugar, and all other vegetable acids, into the acetous; and of the acid of tartar, and all but the acetous, into the saccharine acid; yet no instance has ever occurred of any conversion in the contrary order; that is, of the acetous into any other acid, or of the saccharine acid into the acid of tartar, or any other vegetable acids, excepting the acetous. Westrumb tried to convert vinegar into saccharine acid by abstracting it repeatedly from acid of tartar, but without any success\*.

The theory of the component parts of vegetable acids, that is to say, of those bases which in combination with vital air form acids, embraces the whole chemical theory of organized matter, into which much of conjecture must necessarily enter. When we consider, that in every chemical process with these substances, new combinations take place, at the same time that decompositions are effected; that many or most of the products assume the elastic state, and consequently are more difficultly weighed, measured, and examined; that the constitution of azotic or phlogisticated air is still a matter of doubt; that the basis of fixed air, a fluid so universally produced or extricated, and proved by Lavoisier to be acidified charcoal, is still in some measure an object of controversy; that inflammable air from organized beings is scarcely ever in an uncontaminated state, and is besides an element, the discussion of which embraces the great theory of the composition of water and acids in general; that every other principle obtained from these substances, water and charcoal excepted, is evidently of a compounded nature,

\* Crell, Ann. 1786, t. i. f. 64, and West, Abhandl. and

and with a high degree of probability consists of the preceding matters, with more or less of vital air in certain circumstances;—when this rapid sketch of the composition of organized bodies is reflected on, and extended in its various relations by the philosophical chemist, it will be easily seen that much of conjecture must necessarily enter into this theory;—conjecture which, if luminous and clear, must be productive of bad consequences as well as good. Hypothesis well arranged serves to methodize facts and render them useful, to point out new experiments, and to fix the imagination upon those habitudes of things which result from the existing discoveries: but on the other hand, as the infancy of any science is necessarily attended with a scarcity of facts, and this scarcity can be no otherwise supplied by the author of a conjectural disquisition, than by hazarding bold inferences from what is already known, a large part of such an hypothesis must be doubtful, and this uncertainty will vitiate the general conclusions. If the human mind were capable of being ardent in the pursuit of truth, and at the same time cool and unprejudiced in the rejection of error as soon as discovered, we might with more safety indulge in this method of investigation. But we insensibly become attached to theories in proportion to the labour of investigation they have cost us, and it seems for the most part an easier operation to add an argument or two in support of the theory we have long dwelt on, than to weigh opposite arguments with impartiality, and reject the whole at once if the interests of truth should require it. If it be true, as indeed it is, that the most candid and enlightened among men continually detect this process of delusion in their attempts to investigate the secrets of nature, this consideration must operate as a strong reason why we should patiently endure a state of doubt so long as we do not possess clear indications of the truth; while, on the contrary, we should employ our powers rather in deciding what are the most favourable departments for extensive investigation, than exert our ingenuity in completing the theory of the little we already know.

Considerations of this nature render me unwilling to attempt a discussion of the theory of organized bodies. There is reason to think that their simple elementary parts are few, and that these parts, under peculiar circumstances of exposure, temperature and successive operation, assisted by the texture of the animal or vegetable itself, are combined together by one and one in various proportions, and under various degrees of saturation. For it is well known, that the power and probably the order of the elective attractions are affected by heat, and that the periods of saturation, as in tartarized vegetable alkali, and certain metallic salts, are capable of affording distinct compounds according to the proportions. It also appears more than probable, that triple combinations are afforded by the application of a simple principle to one of these binary combinations. And in these, not only the quantity of the principles and their union, but even the order of their arrangement, are affected by the manner in which the combination was brought about. Thus, as Keir very ingeniously remarks, the combination of alkali and oil may be brought about when the proportion of water to the pure salt is inconsiderable, or when the temperature of the mixture is elevated for a time; and this combination, denominated soap, is then capable of uniting with a large quantity of water. But if the same alkali and oil and water had been at first put together, the water and the salt would have united, and the oil would not have entered into combination. We may carry our reflections as to the compounded nature of organized matters to an extent perhaps not easily limited. In the concrete volatile alkali, we have azotic air, inflammable air, vital air, and charcoal.



coal. If the charcoal could be abstracted, and an additional portion of azotic air added in a certain order of combination, we should have nitrous ammoniac. For the vital air with the principle last added would form nitrous acid instead of fixed air, in which we assume the presence of pure charcoal. Again, if the composition of water be admitted, and the last mentioned salt be dissolved in that fluid, the result will be azotic air combined first with inflammable air; azotic air again separately combined with vital air; and inflammable air combined with vital air. So that the whole number of principles in the solution of the salt will be no greater than before. If the nitrous ammoniac had been dissolved in ardent spirit instead of water, and the spirit be admitted to consist of fixed and inflammable air, the principles will still be the same as before, excepting the addition of charcoal or the base of fixed air. From these instances it may be seen how much depends upon the order, time, situation and proportions of the component parts. And still more, it will in a certain degree be perceived, how much the methods of chemical analysis require to be improved, before we can ascertain by any examination of the compound that order, arrangement, and relative disposition of parts upon which so much of the immediate properties of the compounds depends.

For an extended view of this subject, the reader may have recourse to the article ACIDS VEGETABLE of the larger dictionary of Keir, the numerous writings of Lavoisier, and the antiphlogistic chemists.

The alkalis afforded by the incineration or other management of vegetable matters have already been abundantly treated of under their respective heads. See ALKALIS, also POT-ASH, and PEARL-ASH.

The colouring matters of vegetables are objects of the art of dyeing. These are changed by combination with acids, alkalis, and metallic calces. See DYEING. The colouring principle is found, according to Chaptal, in four states of combination: 1. with the extractive principle; 2. with the resinous principle; 3. with a fecula; and 4. with gum.

When the receptacle of the colour is of the nature of extracts, water takes up the whole, as may be remarked in logwood, turnsole, madder, cochineal, and the like. The colour given to any stuff by immersion in this aqueous solution, is a mere stain capable of being washed out. The art of the dyer consists in impregnating the stuffs with some other principle disposed to combine with the colouring matter, and form an insoluble compound with it. This principle is called the mordant. If the result or compound of the mordant and the colouring matter be totally or nearly insoluble in those fluids which are likely to be applied to the stuff, and the affinity of this insoluble matter to the stuff itself be such as to produce a firm adhesion between them, the tinge or stain will be a good dye.

Those colours which are soluble in spirit of wine only, on account of their resinous basis, are used only in pharmaceutical tinctures, or in the art of dyeing ribbands.

Of colouring matters combined with a fecula, indigo and archil, are leading instances; for which consult the articles respectively.

Such colouring matters as produce a firm dye by treatment with mere water, are supposed to be combined with gum resin, the resinous part of which is concluded to act the part of a mordant.

The pollen or fecundating powder of vegetables differs very little from wax; and

and this last is with considerable probability inferred to consist of a fat oil hardened by the combination of vital air.

Of the ligneous portion of vegetables, or the vegetable fibre, we find but little in the way of research among chemical writers. Its most evident character is insolubility in water and almost every other menstruum. Its expansion and contraction by change of temperature are likewise less than those of any other known substance. It appears however, that its texture or firmness is in some measure altered by heat, attended with moisture, as is shewn in the common instance of bending timber for ship-builders' use. The vitriolic acid applied to wood is decomposed. The wood is brought nearer to the state of coal, and volatile vitriolic acid flies off. The nitrous acid is decomposed upon wood, nearly in the same manner, but appears more disposed to produce the acid state, as is observable when it is applied to cork. Dry wood is so little altered by exposure to the atmosphere, that we know of no process of decomposition or destruction which it undergoes in this exposure, excepting from the action of insects which feed upon it. Chaptal is of opinion, that its component parts are the basis of mucilage, hardened by a greater quantity of vital air in the fixed state. For diluted nitrous acid digested upon *secula* converts it into a substance resembling wood; and he has likewise observed, that those fungi which grow in subterraneous places void of light, and are resolved into a very acid water when left in a vessel to decompose, will acquire a greater quantity of the ligneous principle, if carefully removed so as to vegetate in the light, by which management they are at the same time deprived of their acid principle.

Wood constantly immersed in water, appears to endure at least as well as in the air; but the alternate action of air and water speedily destroys wood by a process called rotting, which is apparently of the same nature as the change produced by the action of nitrous acid.

It should seem as if the combustion of linen and other ligneous matters closely packed together, with a certain proportion of water or oil, as in hay-stacks, or the instances quoted at our article *Pyrophori*, might arise from the transition of vital air frequently perhaps afforded by the wood itself.

Chaptal directs our attention to the transition of mucilage to the state of wood in the growth of vegetables. The cellular envelope which is immediately covered by the epidermis exhibits nothing but mucilage and glands; but by degrees it hardens, forms a stratum of the cortical coating, and at last concludes by becoming one of the ligneous rings.

We observe this transition in certain plants which are annual in cold climates, and vivacious in temperate climates. In the former they are herbaceous, because the periodical return of the cold weather does not permit them to develop themselves. In the second they become arborecent, and the progress of time hardens the mucilage, and forms ligneous coatings.

The induration of the fibrous part may be accelerated by causing the air and light to act more strongly upon it. M. de Buffon has observed, that when a tree is deprived of its bark, the external part of the wood which is exposed to the air acquires a considerable degree of hardness; and trees thus prepared form pieces of carpentry much more solid than those which have not undergone such preparation.

It is probably owing to the large quantity of pure air with which the fibrous matter is loaded, that it is not disposed to putrefy; and it is in consequence of



this most valuable property of not being subject to corruption, that arts have been invented for clearing it of all fermentable principles of the vegetable kingdom, to obtain it in its greatest purity in the fabrication of cloths, paper, &c.

The mixed fluids of plants consist in general of oils, mucilages, salts, and other principles, together with water, much more confused when mechanically extracted by art, than when separately existing in the vessels of the plant. Every reader will readily bring to mind the numerous vegetable products employed as articles of food, or in the manufactures. And these respectively compose so large a part of our work, that an enumeration would be of no apparent utility.

The elastic fluids extricated from vegetables have likewise claimed much of our attention. In the destructive distillation of vegetable matters, the vaporous and elastic products commonly are water, acid, oil, fixed air, and inflammable air. The quantity of this last product is very considerable; and though it holds so much fixed air in combination, that it is not more than five times as light as the air of the atmosphere, yet it has been recommended by Morveau as a cheap material for inflating aerostatic balloons.

**VEGETATION, SALINE.** The crystallization of salts in a fluid is usually ascribed to a disposition of the parts to come together in a certain order, dependent on a principle somewhat resembling that polarity which produces a symmetrical arrangement in particles of steel in the vicinity of a magnet. But there seems to be some other principle concerned in crystallization, which causes the whole structure or group of crystals to occupy more space than before, and in a certain loose mode of expression may be called a disposition in the parts to recede from each other. Thus a drop of water in a very cold atmosphere not only freezes, but puts forth rays in the form of a star, and ice is universally less dense than water. So likewise in the transition of metals from the fluid to the solid state, they not only crystallize internally, but part of the crystals protrude themselves above the common surface, so as to destroy its uniformity, and produce those figures with which the imagination of the alchemists was so much struck. Saline bodies, of which the crystallization forms one of the most common, but by no means the least interesting of the effects of chemistry, likewise exhibit this appearance. For the saline matter of the solutions slowly creeps up the sides of the vessels, passes over the rim and down the external surface.

Mr. Chaptal has given us a good memoir on this subject in the *Journal de Physique* for October 1788, intitled *Observations on the Influence of the Air and Light upon the Vegetation of Salts*.

In the operations in the large way of his manufactory of medical and chemical products, he often observed that salts, particularly the metallic, vegetated on the side most exposed to the light, and the frequency of the effect induced him to make some direct experiments on the subject. For this purpose he took several capsules of glass, and covered the half of each, as well above as below, with black taffetas. At the same time he prepared solutions of almost all the earthy, alkaline or metallic compound salts in distilled water, at the temperature of the atmosphere. These capsules were placed on tables in a well closed chamber which had no chimney, and of which the doors and windows were carefully stopped up, in order that the evaporation might not be hastened by any agitation of the air. Reflected light, by which I understand the light from the clouds, was admitted through a small aperture in one of the window shutters. By this management, as well as the disposition of the capsules, one half of each of their

respective

respective cavities received light from the aperture, and the other was almost perfectly in darkness. The respective solutions were then carefully poured into the capsules by means of a funnel resting on the middle of the bottom, so that the border of the fluid was neat and uniform, without any irregularity or drop of the fluid falling on the bare surface of the glass.

Upwards of two hundred experiments were made with variations of the principal trials, so as to leave no doubt with regard to the constancy of the results. The most remarkable fact is, that the vegetation took place on those surfaces only which were illuminated. This phenomenon was so striking in most of the solutions, that in the space of a few days, and frequently even within one single day, the salt was elevated several lines above the liquor upon the enlightened surface, while there did not appear the smallest crust or edge on the dark part. Nothing could be more interesting than to observe this vegetation, projecting frequently more than an inch, and marking the line of distinction between the illuminated and dark parts of the vessel. The vitriols of iron, of zinc, and other metals, more especially presented this appearance. It was generally observed, that the vegetation was strongest towards the most enlightened part.

This phenomenon may be rendered still more interesting by directing the vegetation at pleasure towards the different parts of the vessel. For this purpose, nothing more is required than to cover the several parts in succession. For the vegetation always takes place in the enlightened part, and quickly ceases in that which is covered.

When the same dissolution has stood for several days, the insensible evaporation gradually depresses its surface, and a crust or edge of salt is left in the obscure part. But the salt never rises, or at least very imperfectly, above the liquor, and cannot be compared with the true vegetation.

When salts are suffered to vegetate in this manner, the spontaneous evaporation of the fluid affords very few crystals. All the saline matter extends itself on the sides of the vessel.

This property of vegetation differs greatly in the several salts. Those which are deliquescent, moisten the sides of the vessel to a small distance above the edge of the fluid, but form neither crust nor ramification. Those salts which are least deliquescent, appeared in general to vegetate the most speedily, and to the greatest height; and among these the metallic salts appeared to have the pre-eminence.

Very singular varieties are observable in the form affected by each salt in its vegetation. In some, among which are the vitriols of iron, copper, zinc, and Glauber's salt, a crust is formed which swells or blisters in proportion to its growth, becomes reduced into leaves, and forms either a series of plates opposed to each other, or blisters of no determinate form.

In other salts, needles are observed to issue from the liquor along the sides of the vessel, and by crossing each other form a very curious kind of net-work. The salt of tin presented our author with one of those very singular appearances. By the too rapid action of aqua regia upon tin, a whitish magma was obtained, which he diluted with water and filtered several times. The solution was always whitish, and in this state was submitted to experiment. Some days afterwards, a saline crust was perceived on the border of the enlightened part of the vessel. This crust increased daily, and appeared to take root in the liquor by a multitude of oblong pyramidal crystals which entered into the solution. The crystals, when once the depression of the fluid had left their extremities bare, joined



joined together by transversal lines, and assumed the most beautiful yellow colour.

It frequently happens that the lines or crystals diverge from a common centre, and form the most beautiful feathers. This appearance was presented by the acetous salt of lime.

The vegetation in many instances forms a thin even covering on the sides of the vessels. Alum, nitre, and sea salt presented this appearance.

The vegetation of certain salts may be favoured by the addition of an excess of acid. Vitriolated tartar is of this kind. It then forms white feathers on the sides of the glass and the surface of the liquor, which sometimes entirely cover it, and crown the borders of the vessel in the most agreeable and striking manner. A large swan's feather does not exceed these vegetations either in whiteness or beauty. Chaptal obtained some which were eight or ten inches in diameter. They soon effloresce if the vessel be not supplied with a due quantity of the solution, because this vegetation draws up a large quantity of fluid in a short time.

This chemist observed, that when the acid solution was charged with vitriolated tartar in excess by the assistance of heat, the salt is precipitated in fine crystals of vitriolated tartar at the simple temperature of the atmosphere, and these crystals have no excess of acid. But if distilled water be saturated with vitriolated tartar at the temperature of the atmosphere, and the same excess of acid be added, the salt afforded by spontaneous evaporation will have an excess of acid. The form of these crystals was constantly that of a six sided flattened prism, terminating in two facets. From these phenomena Mr. Chaptal was led to believe, that light is the sole determining cause of vegetation, but subsequent experiments convinced him that air is the principal agent.

1. A solution of copperas in a capsule well enlightened and covered with a clean glass, afforded no appearance of vegetation.

2. A similar solution left in a very obscure place, vegetated in that part only which was uncovered, but more slowly than when a greater quantity of light was admitted.

3. The solution placed in a well closed bottle, reversed upon water and exposed to day-light, does not vegetate.

4. The vegetation takes place sooner in a very open vessel, such as a cup, than in a cylindrical vessel; sooner in this last than in an uncorked bottle; and in closed vessels not at all.

If a glass funnel be reversed in a capsule containing a saline solution, the vegetation takes place on the external surfaces, but scarcely at all within. It appears therefore that the access of air and its free circulation are peculiarly advantageous to the production of this appearance.

It must be observed that the nature of the vessels is not a matter of indifference in these experiments. Glass is very proper, and metals much less so. But Chaptal remarks, that the phenomenon does not arise from an affinity between the vessel and the fluid, because if so the exposure and light would not be required.

Similar experiments on the vegetation of salts which effloresce on the surface of earths, afforded results of the same kind. He affirms that they all depend on the action of the air, slightly assisted by the concurrence of light. The contact or privation of these agents either favours or interrupts the effect. The nitrous, aluminous or vitriolic earths exhibit striking effects of this kind. Their vegetations are often five inches in length.

The author is averse to entering into conjecture relative to this appearance. He only demands whether it be a kind of affinity between the air, light and saline substances, which elevates the latter contrary to their gravitation? Or is it, he demands, a virtue truly vital which the contact of air determines and fomented? It cannot be denied, but that much of obscurity attends the consideration of what happens among the particles of matter, and that the caution of this author is to be applauded for encouraging a disposition to generalize the facts, rather than to multiply speculations. I shall likewise therefore avoid any attempt at particular explanation, but the following facts seem to throw some light on the subject.

Crystallization, properly so called, is an effect of the mutual tendency of the parts of a body to come together, and takes place whenever the quantity of solvent becomes diminished. See CRYSTALLIZATION. When the quantity of solvent is slowly diminished, and external agitation prevented, the crystals are large and of a determinate figure; but in opposite circumstances they are small, irregular, and in confused groups. The presence of light is found to interrupt crystallization nearly in the same manner as agitation would have done. The vegetation of salts consequently appears to be of a distinct nature in certain respects from crystallization within a fluid. The crystallization which approaches most nearly to vegetation is effected when a thin covering of saline solution is spread out upon a pane of glass. In this case the attractions of the particles of the salt to each other, are all nearly in the same plane, and may therefore, notwithstanding the speedy evaporation, be expected to produce effects more symmetrical than when a much greater thickness of fluid is said to crystallize. The manner in which the air acts is a subject of no difficulty; since it favours the crystallization by abstracting the water. But the agency of light in the experiments of Mr. Chaptal is much more obscure. Experiment leads us no farther than to assert that it singularly favours the assumption of the elastic state, inasmuch that principles which in the dark would have remained united, become separated by the agency of light which gives elasticity to one or more of them. This is seen in the decomposition of nitrous acid in half-filled vessels; the extrication of vital air from vegetables, and other similar effects. Simple evaporation is likewise so far favoured or modified, that the fluid in a closed vessel or bottle partly filled with water or saline solution, rises and is condensed in drops on the side nearest the light. This fact helps us forward in a certain degree. For the light must raise part of the solution, whether merely aqueous or saline, on that side of the vessel which is most illuminated; and when once the surface is wetted, the saline solution will rise to a certain height by cohesive attraction. In this situation, it becomes the film of liquid exposed on a pane of glass. Speedy evaporation affords crystals more or less regular, on the same principle as ramified crystals are produced in the instance last mentioned. The interstices between these minute crystals are capillary tubes, which carry up more of the saline solution, which is distributed by the agency of light as before, and the vegetation goes on. Hence it appears, that a want either of light or of air must suspend the process, since it is in vain that the light is found to spread the fluid over the surface in a closed vessel, if there be not enough of air in succession to crystallize the salt by evaporation. The ingenious author remarks, that the vessels themselves are not indifferent as to the production of this phenomenon. He thinks that it cannot arise from an affinity between the saline solution and the matter of the vessel; but the reason he gives for this opinion is far from being conclusive. For the absolute necessity



necessity of two agents in the production of a phenomenon, does not exclude a third efficient cause. If three causes be jointly necessary, the absence of any one of them will be incompatible with the production of the effect. I am disposed however to think, that the different properties of the vessels in this behalf arise either from their nature as conductors of heat or electricity, or else their transparency. It is well known from the numerous instances adduced by Muschenbroek, that the dew falls plentifully upon dishes of certain materials, and avoids others. The exhalation and condensation here observed as a consequence of the agency of light, will in all probability be modified by the cause which affects the distribution of the dew: what that cause is must be left to future researches.

**VEINS.** The ores of metals are frequently found to fill certain clefts in mountains. These masses, when they run out in length, are called veins. Inconsiderable veins which diverge from the principal are called slips; and such masses of ore as are of considerable magnitude but no great length, are called bellies, or stock works. See **METALS**, **METALLURGY**, and **ORES**.

**VENUS.** The name of the planet Venus has been given to copper, but it is now scarcely ever used. The chemical character or sign of copper is the same as the astronomical character of the planet. See the plate of **Chemical Signs**.

**VERDIGRISE** is copper corroded, and reduced to a very beautiful green rust, by a vinous acid. This matter, which is useful to painters, is conveniently manufactured at Montpellier; the vines of Languedoc, of which that city is the capital, being very proper for this preparation.

The following process for making verdigrise is described by Mr. Monet of the Royal Society of Montpellier, and is published among the *Memoirs of the Academy* for the years 1750 and 1753.

Vine stalks well dried in the sun are steeped during eight days in strong wine, and afterwards drained. They are then put into earthen pots, and upon them wine is poured. The pots are carefully covered. The wine undergoes the acetous fermentation, which in summer is finished in seven or eight days, but requires a longer time in winter, although this operation is always performed in cellars. When the fermentation is sufficiently advanced, which may be known by observing the inner surface of the lids of the pots, which during the progress of the fermentation is continually wetted by the moisture of the rising vapours, the stalks are then to be taken out of the pots. These stalks are by this method impregnated with the acid of the wine, and the remaining liquor is but a very weak vinegar. The stalks are to be drained during some time in baskets, and layers of them are to be put into earthen pots with plates of Swedish copper, so disposed that each plate shall rest upon, and be covered with layers of stalks. The pots are to be covered with lids, and the copper is thus exposed to the action of the vinegar, during three or four days or more, in which time the plates become covered with verdigrise. The plates are then to be taken out of the pots, and left in the cellar three or four days; at the end of which time they are to be moistened with water, or with the weak vinegar above mentioned, and left to dry. When this moistening and drying of the plates has been thrice repeated, the verdigrise will be found to have considerably increased in quantity, and it may then be scraped off for sale.

A solution or erosion of copper, and consequently a verdigrise, may be prepared by employing ordinary vinegar instead of wine, as is directed in the above process.

process. But it would not have the unctuousity of ordinary verdigrise, which quality is necessary in painting. Good verdigrise, according to Macquer, must be prepared by means of a vinous acid, or solvent half acid and half spirituous. Accordingly the success of the operation depends chiefly on the degree of fermentation to which the wine employed has been carried: for this fermentation must not have been so far advanced, that no sensibly vinous or spirituous part remained in the liquor.

Verdigrise is used for painting, as it furnishes a fine green colour, when mixed with oil. It enters also as an ingredient into several plaisters and ointments. In chemistry, verdigrise is used for the extraction of radical vinegar, and for the preparation of crystals of verdigrise, or of Venus.

The above is copied from Macquer. Chaptal informs us, that the fabrication of this article was till lately confined to Montpellier, from a prejudice that the cellars of that city alone were proper for the operation. His account of the manufacture is less ample than the foregoing, but in effect the same. This article is also made at Grenoble, where ready made vinegar is used and sprinkled on plates of copper. This verdigrise contains one sixth part less of copper than that of Montpellier, and has not the empyreumatic smell of the latter. The vinegar it affords by distillation is likewise stronger and in greater plenty. Whence he concludes, that part of the calx of copper in this compound is really dissolved, and brought into the saline state.

VERDITER is a blue pigment, obtained by adding chalk or whitening to the solution of copper in aqua fortis. It is prepared by the refiners, who employ for this purpose the solution of copper, which they obtain in the process of parting, by precipitating silver from aqua fortis with plates of copper. See PARTING. It is said, that a fine coloured verditer cannot be obtained from a solution of copper prepared by dissolving directly that metal in aqua fortis; and that the silver is necessary. We know that it is actually made of a good quality by the refiners only. Dr. Merret says, that it is prepared in the following manner: A quantity of whitening is put into a tub, and upon this the solution of the copper is poured. The mixture is to be stirred every day for some hours together, till the liquor loses its colour. The liquor is then to be poured off, and more solution of copper is to be added. This is to be repeated till the whitening has acquired the proper colour. Then it is to be spread on large pieces of chalk, and dried in the sun.

We have two kinds of verditer in the English market: the one, called refiners verditer, has the form of a very soft impalpable powder, and possesses a stronger body of colour than the other. The other verditer has the form either of hard irregular lumps or powder, in which last state it is much harsher to the feel, and is by no means so readily diffusible in water. The best verditer is, as I understand, made by the refiners, not because their solution of copper possesses any peculiar advantage over any other nitrous solution, but because they obtain it more cheaply than if the acid had not been already paid for in their process of parting. The value of the article is not sufficient to pay for the expence of a direct solution in this country. Common verditer is made from the vitriol of copper, which may be had at a reasonable rate from the manufacturers at Sheffield and Birmingham. I am not acquainted with that part of their manufactories which afford it, but understand that it is not produced in a direct way, but from clippings of metal or other savings. It is frequently contaminated with iron. The copper of a solution of this vitriol is precipitated by an addition of lime in the making of  
common



common verditer. Whiting will not effect a separation. The precipitate afforded by the lime is blue, but requires some management as to the quantities of water as well as of the other principles, and the method of the drying, to produce the best effect. The faintness or harshness of the common verditer, arises no doubt from an admixture of selenite; whereas in the refiners verditer little of lime is found, because the nitrous salt of lime is very soluble in the water. If the object should be found of sufficient commercial importance, it is probable that the blue calx of copper in verditer might be obtained by an indirect process of transferring nitrous acid to the metal. Thus, if the solutions of nitre and of vitriol of copper be mixed, the alkali unites with the vitriolic acid, and vitriolated tartar falls down, if the quantity of water be not considerable, at the same time that the nitrous acid transferred to the copper remains in solution. Other methods of decomposition might be easily pointed out, but every thing of this nature must be referred to the test of experiment. For in some instances, triple compounds are formed where perfect decomposition was expected, and in most instances the completeedulcoration of the product is required, and many apparently minute circumstances must be investigated and attended to, where so delicate a thing as the colour of a metallic calx is the object aimed at. The refiners verditer is more than twice as dear as the common. Both are used in water colours only, chiefly by the paper stainers. It is said that the greater intensity of colour added to the facility with which it may be uniformly spread over any surface, affords the advantage even of cheapness to the refiners verditer; but the last mentioned quality is communicated to common verditer, by steeping it for several days in water before it is used.

In the 13th volume of the *Annales de Chimie*, is inserted a chemical examination of verditer, by Peltetier, extracted from a memoir read to the Academy of Sciences. After giving a short history of the article according to the usual and excellent custom of the French writers, he proceeds to relate his own experiments. He used that article which we call refiners verditer. 1. Verditer was totally dissolved in the nitrous and marine acids, and fixed air was separated with effervescence. 2. The vitriolic acid attacked verditer with strong effervescence, so as almost to throw the mixture out of the matrafs. The solution was not perfectly clear. After evaporation to dryness, distilled water was added. It took up the whole, which was found to be selenite and vitriol of copper. The former was first separated by evaporation, and afterwards the latter. From these products it was ascertained that a hundred grains of the verditer contained seven grains of lime, and fifty grains of pure copper. The inferior verditers were found to contain more lime and less copper, the quantity of the former in some amounting to near 14 grains. Their colour was accordingly less intense. 3. Volatile alkali takes up the copper from verditer, and leaves a small portion of mild calcareous earth. But the numerical results of this experiment could not be depended on, because the chalk exists in the verditer so minutely divided, or perhaps because it unites with the compound in the solution, and cannot therefore be well separated. 4. By distillation in the pneumatic apparatus, by a gradual heat, a loss of accurately two thirds of its weight was experienced. The volatile product was almost totally air, soluble in water, converting tincture of turnsole to a red, and precipitating lime water. It was therefore fixed air. A few drops of water were perceived in the neck of the retort, which being deducted by estimate from the weight of the elastic product left 30 per cent. of fixed air. 5. The residue of this distillation was divided into two parts, and reduced with a proper quantity

of black flux, and charcoal with common salt. The quantity of copper in one of these reductions proved to be 49 parts in the hundred of the original weight of verditer, and the other proved to be 49 $\frac{1}{2}$ . With a small allowance therefore, for loss and inaccuracy, this result may be taken as a confirmation of the humid analysis, which gave 50. 6. The quantity of vital air in the calx was ascertained by inference from the preceding facts. From a hundred parts, the products were 30 fixed air, 3 $\frac{1}{2}$  water, 7 lime, and 50 copper. In order to complete the hundred parts, it is necessary to add 9 $\frac{1}{2}$ . This will be the weight of vital air. With a view to ascertain more perfectly that vital air is really contained in verditer, a certain quantity was distilled till it afforded no more fixed air. A little charcoal in powder was then added, and the distillation being renewed, more fixed air was obtained, which M. Pelletier considers as a conclusive proof of the existence of vital air in the calx.

Hence it follows that 100 grains of the very best verditer contain, of fixed air 30, of water 3 $\frac{1}{2}$ , of pure lime 7, of oxygene or vital air 9 $\frac{1}{2}$ , and of pure copper 50. The author a second time remarks, that the verditers of inferior quality contain more chalk and less copper. It is not directly asserted, that the other principles in these verditers are unaltered in their proportions. In the above numbers it is observable, that more fixed air enters into the compound than is requisite to convert the lime into chalk. The rest must therefore, in all probability, have united with the calx of copper. Whether the blue colour be owing to its presence chiefly, is an object deserving more minute enquiry. It is also observable, that M. Pelletier's humid analysis by vitriolic acid, is not alone sufficient to shew that the lime in the common verditers did not possess the form of selenite, instead of that of chalk.

The most perfect analysis in the present state of chemistry, as has already been remarked, under the article Vegetables, can only shew the component parts, but not the order of their union. It therefore by no means follows, that the above principles in the same precise proportions must unite and make verditer; but it will be requisite that a definite calcination of the copper, a certain division, or state either of solution or precipitation, or in a word, other circumstances relative to the order of their union, of which we know so little, should take place. M. Pelletier had therefore no inconsiderable part of his task remaining to be done, before he could produce the required compound. He was acquainted with the fact, that the refiners prepare the best verditer, and that an inferior kind of verditer is made at Paris by precipitating vitriol of copper by vegetable alkali, and converting it to a blue by lime and sal ammoniac. This verditer becomes greenish as it dries. He was likewise aware that Berthollet had remarked that the greenish precipitate of copper recently made, and sufficiently diffused in water, assumes in time, after quick lime has been added, a blue colour, greatly resembling that of verditer. He made many trials without success, some of which he relates. They deserve the notice of chemists, but I omit them because less immediately connected with the subject. He used a nitrous solution of copper, and precipitated by the alkalis as well mild as pure. A piece of chalk kept for some days in this solution, assumed a very fine green colour, resembling malachite. The most promising experiments were those in which lime was the precipitant. It was found that the precipitates were pale green when the proportion of lime was small; but when this proportion was greater than enough to decompose the whole of the nitrous solution, the precipitates were blue, of more or less intensity. His successful process was the following:



Copper was dissolved without heat in diluted nitrous acid. To this, lime in powder was added with agitation, in such a quantity as to decompose nearly the whole of the nitrous solution, but not in excess, in order that the precipitate might be a pure calx of copper. After subsidence, decantation of the nitre of lime, edulcoration with water, and drying upon a cloth, the precipitate was obtained of a pale green colour. A certain quantity of this, with the addition of as much water, if the mass has been suffered to dry, as is sufficient to convert it into a thin paste, was put into a large mortar, or upon the grinding-stone of the colour-makers. It was then triturated with a small portion of lime in powder. At the instant of this addition, the mass assumed a lively blue colour. The quantity of lime made use of is from 7 to 10 per cent. of the weight of the precipitate. But this quantity may be ascertained by trials of a small quantity of the mixture, which may be dried either in the sun, or in a warm place during the time of triturating. If its colour when dry appears too pale, a small quantity of the precipitate of copper may be added to the mass, taking care that it shall not be enough to make any difference in the liveliness of the blue. The whole is then to be dried, which is speedily done, and the mass then proves to be of a colour equal, or even superior to the verditer of England, and possessing the same habits when chemically analysed. The influence of light is of no consequence in this operation. For the conversion is instantaneous, and takes place in the dark.

M. Pelletier is of opinion, that the lime takes the vital air from the calx of copper. I have been disposed to suspect the formation of volatile alkali in this process, which still deserves to be further examined. He distinguishes verditer from the crystals of azure, because these last are a combination of copper with fixed air, and from malachite, which may be considered as a combination of fixed air with copper superoxygenated.

#### VESSELS CHEMICAL. See APPARATUS.

VINEGAR is an acid produced by a peculiar fermentation from vinous liquors. Its qualities depend much on the method of exciting and of conducting that fermentation. The wine which is generally converted into vinegar, and which for its cheapness is generally employed for this purpose, is such as has become already sour; although the better and the more spirituous the wine is, and also the more of the vinous spirit that can be retained in the vinegar, the better and stronger this will be. Becher says in his *Physica Subterranea*, that having digested wine in order to convert it into vinegar in a bottle hermetically sealed, he found, that although a longer than the ordinary time was required, the vinegar produced was much stronger than when free air is admitted. M. Cartheuser also affirms, that the strength of vinegar may be much increased by adding some ardent spirit to the wine before it is exposed to the acetous fermentation.

Different methods are practised by manufacturers for making vinegar, who are generally believed to be possessed of some secret for that purpose. Nevertheless, no more seems requisite in the preparation of good vinegar, than to employ good wine, and to conduct the fermentation in the most advantageous method; in the same manner as good wine can only be made from good must, and by a well conducted fermentation. The principal part of these operations is performed by nature.

The method of making vinegar consists in mixing the wine to be fermented with its dregs and its tartar, and in exposing this liquor to a heat of about seventy or eighty degrees. This fermentation seems to require more heat than the

the spirituous. It also excites more heat and tumult; and although it ought to be allowed to proceed briskly, yet it is necessary from time to time to check it.

Boerhaave describes, in his Elements of Chemistry, the following process, which seems to be well contrived for the making of vinegar.

Take two large oaken vats or hogheads, and in each of these place a wooden grate or hurdle at the distance of a foot from the bottom. Set the vessel upright, and on the grate place a moderately close layer of green twigs, or fresh cuttings of the vine. Then fill up the vessel with the footstalks of grapes, commonly called the cape, to the top of the vessel, which must be left quite open.

Having thus prepared the two vessels, pour into them the wine to be converted into vinegar, so as to fill one of them quite up, and the other but half full. Leave them thus for twenty-four hours, and then fill up the half-filled vessel with liquor from that which is quite full, and which will now in its turn only be left half-full. Four-and-twenty hours afterwards repeat the same operation, and thus go on, keeping the vessels alternately full and half-full during every twenty-four hours till the vinegar be made. On the second or third day there will arise in the half-filled vessel, a fermentative motion, accompanied with a sensible heat, which will gradually increase from day to day. On the contrary, the fermenting motion is almost imperceptible in the full vessel; and as the two vessels are alternately full and half-full, the fermentation is by that means in some measure interrupted, and is only renewed every other day in each vessel.

When this motion appears to have entirely ceased, even in the half-filled vessel, it is a sign that the fermentation is finished, and therefore the vinegar is then to be put into casks close stopped, and kept in a cool place.

A greater or less degree of warmth accelerates or checks this, as well as the spirituous fermentation. In France it is finished in about fifteen days, during the summer; but if the heat of the air be very great, and exceed the twenty-fifth degree of Reaumur's thermometer, the half-filled vessel must be filled up every twelve hours, because if the fermentation be not so checked in that time, it will become violent, and the liquor will be so heated that many of the spirituous parts, on which the strength of the vinegar depends, will be dissipated, so that nothing will remain after the fermentation but a vapid liquor, sour indeed, but effete. The better to prevent the dissipation of the spirituous parts, it is a proper and usual precaution to close the mouth of the half-filled vessel in which the liquor ferments, with a cover made of oak wood. As to the full vessel, it is always left open, that the air may act freely on the liquor it contains; for it is not liable to the same inconveniencies, because it ferments but very slowly.

In the Dictionnaire Portatif des Arts et Metiers, another method is described, by which a very good vinegar is commonly made at Paris, from the lees of wine. For this purpose all the wine contained in the lees is pressed out and put into large casks, the bung holes of which are left open. These casks are put into a hot place, and if the fermentation proceeds too fast, it must be checked by adding more fresh wine. The process is very similar to the foregoing.

The appearances which accompany the acetous fermentation, resemble much those that occur in the spirituous fermentation. In both fermentations, an intestine motion, a swelling, a hissing noise, and an ebullition may be perceived. There are, nevertheless, essential differences between them. Besides that the products



products of the vinous and acetous fermentations differ exceedingly, the heat produced by the former is scarcely sensible, while that produced by the latter is considerable. Again there is reason to believe, that the vapour which exhales from vinegar during fermentation is not noxious, as the vapour of fermenting wine is; at least, it has not been observed to produce such bad effects. On the contrary, as the acid of vinegar more and more disengages or unfolds itself, it seems to acquire more power to retain the basis of fixed air, which is the truly dangerous part of the vapours of fermentation. Lastly, vinegar does not deposit tartar as wine does, even although it has been made with wine that had not deposited its tartar. But the sediment of vinegar is a viscid, oily, and very putrescent matter. The grape-stalks used in the making of vinegar, to promote and increase the fermentation, are covered over with this matter during the operation. They are generally washed clean, and carefully preserved to promote the fermentation of more vinegar, because the acid with which they are soaked, acts powerfully as a leaven or ferment. The casks also which have been used for the preparation of vinegar are to be cleansed from the abovementioned viscid matter, and kept for the same use, as they are rendered fitter than new casks for the preparation of vinegar.

It appears that the strength of vinegar is impaired by too speedy fermentation in vessels not at all stopped, most probably from the escape of ardent spirit, which certainly contributes to its formation. Hence small casks or vessels imperfectly closed, are best suited to this process. In England the vinegar makers use several hundreds of casks disposed in the open air, with the bung-hole upwards, and covered each with a tile to exclude the rain. Beer is brewed of a proper strength from malt for this express purpose. The addition of hops is not here used.

Milk also affords vinegar by fermentation. This fluid does not afford ardent spirit enough to favour the operation, which therefore requires either the addition of a small portion of spirit, or a considerable heat, such as that of a warm oven for two or three days.

Much ingenious reasoning has been offered by philosophers on the effects of the acetous fermentation, and the component parts of vinegar. The leading and established facts are, that ardent spirit appears necessary for the production of this acid by fermentation, and that vital air is absorbed in the process. Hence it appears to follow that ardent spirit contains the acidifiable basis of vinegar. From the order of convertibility of vegetable acids into each other, it is rendered highly probable, that these have one common basis, and differ only in the greater or less degree of acidification. The most perfect and last state of vegetable acidification is fixed air. Lavoisier has offered proof that charcoal consists almost totally of the basis of fixed air.

Glass vessels are preferable for the distillation of vinegar, as well as for most other chemical operations, where their size and the required heat will permit. Earthen or stone ware vessels may also be used. For larger quantities a copper alembic with a glass head and worm pipe of pure tin is recommended. Some direct that the inside should be tinned, and others that it should be smeared with grease. This last contrivance does not seem to promise much advantage, and may vitiate the acid, since Rozier remarks, that fat oils and vinegar have some action on each other in distillation. There is probably nothing to fear from the bare copper, if the vinegar be poured in hot. For the confectioners have long since remarked, that hot vinegar does not corrode or receive any impregnation from their copper vessels, though there is much danger in suffering it to remain

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in them cold. This has been explained, not from the difference of temperature, but the exclusion of the external air by the vapours of the hot fluid, which in neither case can act on the copper, unless vital air be present to be absorbed. Distilled vinegar is called the acetous acid.

Dr. Croll, in the *Journal de Physique* for October 1785, has given a set of experiments to shew that all the vegetable acids are convertible into one, and that the primitive acid is contained in the purest spirit of wine. His reasoning and inductions are conformable to the theory of phlogiston. Most chemists at present, whatever may be the theories they maintain, would find it necessary to attend strictly to the agency of vital air in processes of this nature. I give the experiments in the words of the English translation at the end of Scheele's *Essays*. These may be compared with the facts adduced under the article *Vegetables*.

1. If the residuum of dulcified spirit of nitre be boiled with a large quantity of nitrous acid, care being at the same time taken to condense the vapours by a proper apparatus; and if the liquid which has passed over be saturated with vegetable alkali, nitre and terra foliata tartari will be obtained. If the latter be separated by means of spirit of wine, the vinegar may be got by the ordinary process.

2. Upon boiling the residuum over again with nitrous acid, the same products are obtained. The oftener this process is repeated, the less is procured of acid of sugar, and at length no vestige of it is to be found.

3. If pure acid of sugar, completely formed, be boiled with twelve or fourteen times its quantity of nitrous acid, the former disappears, and the receiver is found to contain phlogisticated nitrous acid, vinegar, aerial acid, phlogisticated air, and in the retort there remains a little calcareous earth.

4. If the acid of sugar be boiled with six times its quantity of vitriolic acid, there are found in the receiver vinegar, phlogisticated vitriolic acid, aerial acid, and in the receiver pure vitriolic acid.

5. By saturating the residuum of dulcified spirit of nitre with chalk, there is formed an insoluble salt, which on being treated with vitriolic acid, yields a real acid of tartar; for, with vegetable alkali, it constitutes cream of tartar.

6. If the liquor, from which the tartarised lime (tartareous selenite) was procured, be evaporated, there will remain a dark-coloured matter, which yields, on distillation, empyreumatic acid of tartar, and a spongy coal. Hence it appears, that spirit of wine consists of acid of tartar, of water, and phlogiston; so that it is a native dulcified acid; and nitrous acid, on being mixed with it in moderate quantity, dislodges the acid of tartar. If more nitrous acid be added, the acid of tartar is converted into acid of sugar and phlogiston; and by adding a new portion of nitrous acid, the acid of sugar is changed into vinegar.

7. If one part of acid of sugar, together with one and one-half part of manganese, be boiled with a sufficient quantity of nitrous acid, the manganese will be almost entirely dissolved, and vinegar, with phlogisticated nitrous acid, pass over into the receiver.

8. If acid of tartar and manganese be boiled with vitriolic acid, the manganese will be dissolved, and vinegar, with vitriolic acid, be obtained.

9. When acid of tartar, manganese and nitrous acid, are boiled together, the manganese is dissolved, and vinegar, together with phlogisticated nitrous acid, is obtained.

10. If acid of tartar and spirit of wine be digested together for several months, the



the whole is converted into vinegar, and the air in the vessel becomes partly fixed, and partly phlogisticated air.

11. If spirit of wine be boiled with vitriolic acid and manganese, it will be converted into vinegar and phlogisticated air.

12. Spirit of wine, by being distilled upwards of twenty times from off caustic alkali, was changed into vinegar, and a considerable quantity of water was obtained.

Hence it follows, according to Crell, that the acids of tartar, and of sugar, and vinegar, are modifications of the same acid, as it contains more or less phlogiston, or as the modern chemists would say, less or more acidified by vital air. The acid of tartar has the greatest quantity of the phlogiston; the acid of sugar a little less, and vinegar has the smallest quantity. Or if the real principle, vital air, be considered, its quantities in these are in the inverted order, more instead of less. In these experiments, it is necessary to employ nitrous acid and fixed alkali, without any admixture of marine acid, otherwise the observer will be led into mistakes.

Vinegar, as an acid, unites with all the alkalis, some earths, and most of the metals; and with these bases it forms compounds, some of which are crystallizable, and others have not yet been reduced to a regularity of figure.

The affinity\* of the acetous acid to these substances, is inferior to that of most of the other acids, even of the vegetable and animal kingdoms, as appears from Bergman's table of affinities. The acetous salts are easily decomposed by other stronger acids, especially by the vitriolic, nitrous, and marine; and at the same time the acetous acid may be procured by distillation. These salts may likewise be decomposed merely by heat; but in this process the acetous acid is also decomposed, and changed chiefly into fixed and inflammable air, in all those instances where the acid is so strongly combined with the basis of the salt, as to require a certain considerable degree of heat to effect its separation.

With ponderous earth the saline mass formed by the acetous acid, does not crystallize; but when evaporated to dryness, it deliquesces by exposure to air. This mass is not decomposed by acid of arsenic. Bergman, Nov. Act. Ups. ii. 223. Although this earth is placed by Bergman at the head of the column of the acetous acid in his table, as having the greatest affinity, he acknowledges that this superiority is not founded on experiment.

With fixed vegetable alkali this acid unites and forms a deliquescent salt scarcely crystallizable, called improperly foliated earth of tartar, and regenerated tartar.

With mineral alkali it forms a crystallizable salt, which does not deliquesce. To this salt no name has been generally given, but it may not improperly be called acetous salt of mineral alkali.

The salt formed by uniting vinegar with volatile alkali, called by the various names of spirit of Mindererus, liquid sal ammoniac, acetous sal ammoniac, and by Bergman, alkali volatile acetatum, is generally in a liquid state, and is commonly believed not to be crystallizable, as in distillation it passes entirely over into the receiver. It nevertheless may be reduced into the form of small needle-shaped crystals, when this liquor is evaporated to the consistence of a syrup.

\* These affinities and compounds are from Keir's Dict. *Acid acetous*.

Westendorf, by adding his concentrated vinegar to mild volatile alkali, obtained a pellucid liquid which did not crystallize, and which by distillation was totally expelled from the retort, leaving only a white spot. In the receiver under the clear fluid a transparent saline mass appeared, which being separated from the fluid, and exposed to gentle warmth, melted, and threw out abundance of white vapours, and in a few minutes shot into sharp crystals resembling those of nitre. These crystals remained unchanged while cold, but, when melted by a gentle warmth, they smoked and evaporated. Their taste at first was sharp and then sweet, and they possessed the general properties of neutral salts.

The salt formed by dissolving chalk or other calcareous earth in distilled vinegar, called salt of chalk, or fixed vegetable sal ammoniac, and by Bergman calx acetata, has a sharp bitter taste, appears in the form of crystals resembling somewhat ears of corn, which remain dry when exposed to air, unless the acid has been superabundant, in which case they deliquesce. By distilling without addition, the acid is separated from the earth, and appears in the form of a white acid and inflammable vapour, which smells like acetous ether, somewhat empyreumatic, and which condenses into a reddish brown liquor.

This liquor being rectified, is very volatile and inflammable: upon adding water it acquires a milky appearance, and drops of oil seem to swim upon the surface. After the rectification, a reddish brown liquor remains behind in the retort, together with a black thick oil. When this earthy salt is mixed with a solution of Glauber's salt, the calcareous earth is precipitated along with the vitriolic acid, the acetous acid uniting with the mineral alkali, makes a crystallizable salt, or foliated earth, by the calcination of which to whiteness, the mineral alkali may be obtained. This acetous calcareous salt is not soluble in spirit of wine.

With magnesia, the acetous acid unites, and, after a perfect saturation, forms a viscid saline mass, like a solution of gum arabic, which does not shoot into crystals, but remains deliquescent, has a taste sweetish at first, and afterwards bitter, and is soluble in spirit of wine. The acid of this saline mass may be separated by distillation without addition. See Margraaf's Chemical Works, vol. ii. Wenzel on Affinities, and Bergman on Magnesia.

The earth of alum obtained by boiling alum with alkali, and edulcorated by digesting in an alkaline lixivium, is dissolved by distilled vinegar in a very considerable quantity. (Wenzel, p. 202.) A considerable quantity of the earth of alum, precipitated by alkali, and edulcorated by hot water in Margraaf's manner, (Chemical Works, vol. i. p. 200.) is soluble in vinegar, and a whitish saline mass is then obtained, which is not crystallizable. From this mass a concentrated acetous acid may be obtained by distillation. Margraaf says that he obtained small needle-shaped crystals from a solution of earth of alum in acetous acid.

The acetous acid has no action upon siliceous earth, for the needle-shaped crystals observed by Durande (*Elemens de Chymie*, Dijon, iii. 13.) in a mixture of vinegar with the earth precipitated from a liquor of flints, do not prove the solubility of siliceous earth, as Leonhardi observes.

Zinc is soluble not only in its metallic and calciform states, but also when mixed with other metals, according to the experiments of Messrs. Macquer and Montigni. (*Gazette de Santé*, 1777.) Concentrated vinegar dissolves zinc with much heat, sulphureous smell, and exhalation of inflammable vapour, and forms with it a congealed mass, which being diluted with water, yields oblong sharp crystals, by the first crystallization, and star-like crystals afterwards. Wenzel



says, he obtained foliated talky crystals, and Monnet got from this solution, transparent, friable, talky crystals of a white pearly colour, when bruised, some of a laminated, and others of a granulated form. He observed that this salt, when thrown on the coals, fulminated at first a little, and gave a blueish flame, and then melted, letting its acid escape, while a yellow calx remained. (*Elem. de Chym.* iii. 38.)

The acetous salt of zinc is decomposed by distillation, without addition, according to Hellot, into water, an inflammable liquor, an oil which at first appears yellow, and afterwards green, and white flowers, which burn with a blue flame. Westendorf obtained in this distillation no oil, but some acetous acid; a sweet-tasted empyreumatic liquor containing zinc; a sublimate of flowers which were sweet, soluble in water, and burnt with a green flame; and when a stronger heat was applied, the zinc sublimed in its metallic state, leaving a spongy coal at the bottom of the retort. The solution of zinc in acetous acid gives a green colour to syrup of violets, throws down a white precipitate on adding alkalis, or an infusion of galls, is not precipitated by common salt, vitriolated tartar, vitriolic or marine acids, blue vitriol, or corrosive sublimate, but forms a red precipitate when added to a solution of gold; a white precipitate with solution of silver, a crystalline pearly precipitate with solution of mercury, and crystalline precipitates with solutions of bismuth and of tin. (Westendorf, f. 45.) Bergman says, this acetous solution of zinc is decomposed by the acid of arsenic. (*Nov. Act. Upf.* tom. ii.)

Vinegar dissolves iron with a slight effervescence, caused by the disengagement of an inflammable gas, and acquires a reddish brown colour. The solution when evaporated deposits much ochre, and yields when cold a few deliquescent crystals, according to Monnet. (*Dissolut. des Metaux.*) These crystals have a sweetish, styptic taste: when exposed to distillation their acid escapes, and a yellow calx remains which is attractable by the magnet. But Mr. Gellert says, that the solution yielded by distillation only a watry fluid.

Vinegar has scarcely any action upon manganese, even in a boiling hear. Nevertheless concentrated vinegar by being repeatedly distilled with manganese, becomes saturated, and the salt is deliquescent. (*Scheele on Manganese.*)

Regulus of cobalt is not soluble in vinegar, but its calx gives a pale rose-coloured solution, which has the property of being a sympathetic ink, that receives a green colour from marine acid. This solution is not decomposed by acid of arsenic. (Bergman, *Nov. Act. Upf.* ii. 245.)

Vinegar dissolves nickel, and the solution yields green crystals. (Bergm. de Nicolo, f. 14.)

The easy solution of lead by vinegar, and the salt called sugar of lead thence resulting, are well known.

Tin communicates to vinegar, by means of digestion, a turbid appearance, and a metallic taste. Alkalis precipitate a little from this solution. (Margaaf's *Chem. Works*, vol. ii.) This tin does not adhere strongly to the acid, and yields no crystals by evaporation, but a yellow gummy saline mass, of an unpleasant smell, which does not deliquesce, but melts easily upon coals, swells like borax, and leaves behind a gray spongy ash. This solution of tin in vinegar may be decomposed by iron, zinc, and lead, likewise by vitriolic acid, by common salt, and by alkalis. It forms a black precipitate, when added to a solution of silver, and to a solution of gold a purple precipitate. (Westendorf, f. 35.) The precipitate of tin is not more copiously soluble than metallic tin in concentrated.

concentrated vinegar. (Wenzel, Verw. p. 199.) The calx of tin, which has been strongly calcined either by deflagration with double its quantity of saltpetre, and well edulcorated, or the precipitate from a solution in tin, by means of spirit of sal ammoniac, are so soluble in this acid, that crystals may be thence obtained, which are white, hard, solid, transparent, and sweetish, called Mynsicht's salt of Jove, or salt of tin. This acetous salt of tin may be decomposed by vitriolic acid, by common salt, or by alkali. (Bergman in Scheffer's Chem. Works, p. 237.)

Bismuth and also its calx, according to Pott, (Observ. Chem. vol. i. p. 167.) are soluble in acetous acid, with which they form a bitter acrid liquor, which cannot easily be brought to crystallize. Wenzel also mentions the solubility of bismuth in this acid, (Verw. p. 204.) and says that upon evaporating the solution a yellow mass is left, which is no longer soluble in water. He says that bismuth is more soluble in its metallic than calciform state. However, that its calx is also in some degree soluble in the acetous acid, appears from Bergman. (Nov. Act. Ups. tom. ii. p. 242.)

Westendorp's concentrated vinegar seemed to have but little action on bismuth, for 1 $\frac{1}{2}$  ounce of the acid, with a digestion of twelve hours, dissolved only eleven grains. (Loc. citat. f. 41.)

The above authorities prove clearly that the authors of the *Elemens de Chymie*, à Dijon, are mistaken in their assertion of the absolute unsolubility of bismuth, or of its precipitate, in acetous acid. (Tom. iii. p. 37.)

The regulus of antimony is scarcely acted upon by the acetous acid, even when a boiling heat is applied, according to Wenzel and Monnet. Nevertheless it appears to be dissolved in sufficient quantity, not only by vinegar, but even by wine, to impart to these liquors an emetic quality. But this quantity may be too minute to be discovered by weighing. Westendorp has also observed, that the vinegar digested on regulus of antimony gives a greenish colour to the Prussian lixivium, although it does not give any indication of iron to infusion of galls; and that when this vinegar is abstracted, an appearance of a sublimate and a metallic residuum shew that there had been some degree of solution. The calx and glass of antimony are somewhat more soluble in this acid. The powder precipitated from a solution of regulus of antimony in aqua regis, by means of fixed alkali, is soluble in concentrated vinegar, but the solution on evaporation is not crystallizable according to Wenzel. This solution may be decomposed by acid of arsenic. (Bergman, Nov. Act. Ups. ii. 246.)

The regulus of arsenic is not soluble in this acid, but its calx may be dissolved either in common or distilled vinegar. Cadet (Scavans Etrang. iii.) obtained a smoking liquor by distilling a mixture of white arsenic and foliated earth. The authors of the *Elemens de Chymie*, à Dijon, iii. 39. repeated and extended this enquiry, and met with some curious results, of which Keir gives a translation. The substance is as follows:

1. Five ounces of distilled vinegar were digested on a sand bath, upon white pulverized arsenic. The filtered liquor was covered during evaporation with a white saline crust, in quantity two gros eight grains. From some trials on animals it was much less noxious than arsenic itself. 2. To a solution of this crust in water a solution of alkali was added, (I suppose veg. alk.) a salt in irregular crystals was formed in the course of some days, which threw down a yellow precipitate from the nitrous solution of silver. 3. A mixture of equal parts of



foliated earth and white arsenic afforded at first a small quantity of clear fluid, in which acid predominated. And the second product separately received was a reddish brown liquor of an abominable smell, which filled the receiver with fumes. Towards the end of the operation, a black powder sublimed to the neck of the retort, together with a little reguline arsenic, and a substance which took fire like sulphur upon the application of a lighted candle. 4. The red liquor preserved its property of smoking when cold, and emitted the same detestable smell. It gave slight indications of acidity.

These chemists were desirous of examining a yellowish matter of an oily appearance, which had subsided to the bottom of the bottle. For this purpose they carefully decanted the supernatant liquor, and poured the remainder upon a filter of paper, when before many drops had passed, there arose a thick smoke, forming a column from the vessel to the ceiling. A slight ebullition of the matter was perceived at the sides of the vessel, and a beautiful rose-coloured flame appeared during some instants. The paper of the filter was burnt at one side, and most of it was only blackened. After the flame was extinguished, a fat reddish matter was observed, which being melted on burning coals, gave a white flame, was considerably distended, and afterwards sunk, leaving a black spot on the coal, which required the utmost heat to be effaced. The liquor had been distilled three weeks, and the bottle had often been opened when these observations were made. The inflammability could not proceed from the concentration of the vinegar, for the rose-colour of the flame, the precipitation of the sublimate, and the fixity of the spot on the coal, prove that these two substances were united, and in a state of combination, which is further evinced by the loss of the inflammable property, when the liquor was decomposed by a fixed alkali. This smell so penetrating and fetid, which exhaled from this new phosphorus, affected the operators with no other inconvenience, than an unpleasant sensation in the throat, which further confirms the above conjecture, that vinegar corrects arsenic.

The saline brown mass that remained in the retort, was partly soluble in hot water, and yielded by evaporation a salt which was not deliquescent, and afforded no perceptible smell of arsenic when placed on burning coals. The residuum after this treatment was mealy, white and fixed; the following day it deliquesced; whence these chemists concluded that it consisted chiefly of alkali which had been enabled to crystallize by receiving fixed air from the vinegar.

Vinegar does not act upon mercury in its metallic state, but it dissolves the metallic calces, as precipitate per se, turbith mineral, and the precipitate formed by adding fixed alkali to a solution of mercury in nitrous acid; with all which preparations of mercury it forms white, shining, scaly crystals, like those of sedative salt of borax.

Concentrated acetous acid does not dissolve silver in its metallic state, but it readily dissolves the yellow calces of silver precipitated from its solution in nitrous acid by means of fusible salt of urine, or volatile alkali; and very copiously with the help of a boiling heat, the precipitate thence obtained by means of fixed vegetable alkali. (Margaaf's Chemical Works, i. treatise 5th.) The last mentioned solution yields shining, oblong, needle-shaped crystals, which are changed to a calx by means of several acids, especially by the marine; and zinc, iron, tin, copper, and quicksilver throw down the silver in its metallic form. (Bergman, Anmerk. zu Scheffer, &c. Westendorf, lib. cit. & Wenzel, Verwandtschaft.)

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The acetous acid makes no impression upon gold in its metallic state. The crude or undistilled vinegar decomposes a solution of gold, and produces a dark violet-coloured, and also a metallic precipitate. Distilled vinegar throws down the gold in its proper state. The precipitate effected by adding fixed alkali, when digested with acetous acid, is of a purple colour (Berg. Nov. Act. Upsal. ii. 237.) Westendorf's concentrated vinegar dissolves not only this precipitate, but also fulminating gold, and the latter very easily. The solution, which is yellow, gives with a volatile alkali a yellow precipitate; with a lixivium of blood, a blue precipitate; and both these precipitates fulminate. The dry salt of gold dissolves in this acid, and gives oblong yellow crystals. (Westendorf. Disp. cit. sect. 12—15.)

Platina is insoluble in the acetous acid, but the precipitate obtained by adding fixed alkali to the solution is soluble in this acid. (Bergm. Nov. Act. Upsal. ii. 238.)

Concerning the action of vinegar on spirit of wine, see ETHER. This acid has no effect upon fat oils, except that when distilled together, some kind of mixture takes place, as the Abbé Rozier observes. (De la Fermentation des Vins, p. iii.) Neither does distilled vinegar act upon essential oils; but Westendorf's concentrated acid dissolved about a sixth part of oil of rosemary, or one half its weight of camphor; which latter solution was inflammable; and the camphor was precipitated from it by adding water.

Vinegar dissolves the true gums, and partly the gum resins, by means of digestion. (Poerner, Delin. Pharm. sect. 35.)

Boerhaave observes, that vinegar by long boiling dissolves the flesh, cartilages, bones and ligaments of animals. (Elem. Chem. ii. proc. 52.)

The Count de Lauraguais obtained highly concentrated vinegar from verdigrise in an icy form. This form has hitherto been entirely ascribed to the cupreous particles combined with, or at least acting upon it; but Mr. Lowitz\* has shewn, that the acetous acid itself possesses the property of assuming a crystallized form.

This chemist prepared a concentrated vinegar (alkohol aceti) by congelation, in the following manner:—He froze a whole barrel of vinegar as much as possible, then distilled the remaining unfrozen vinegar in a water bath; by which means he at first especially collected the spirituous ethereal part; the vinegar which next comes over he froze again as much as possible, and afterwards purified it, by distilling it again with three or four pounds of charcoal powder. By this means he never failed to procure a very pure, sweet-smelling, highly concentrated vinegar; the agreeable odour of which, however, may be still farther improved by the addition of a proper quantity of the ethereal liquor collected at the beginning of the first distillation, but which must be previously dephlegmated by two or three rectifications.

After the distillation on the water-bath was over, that no vinegar might be lost, he removed the retort, with the charcoal powder which remained in it, to a sand-bath; and thus he obtained, by means of a strong fire, a few ounces more of a remarkably concentrated vinegar, which was of a yellow colour.

Having collected about ten ounces of this concentrated vinegar, he exposed it to a cold equal to 195 of De Lisle's thermometer; in which situation it shot into crystals from every part. He let what remained fluid drop away from the

\* Crell's Chemical Journal, English, ii. iii.

crystals



crystals into a basin placed underneath, first in the cold air, and afterwards at the window within doors. There remained in the bottle snow-white finely foliated crystals, closely accumulated upon each other, which at first he took to be nothing but ice: on placing them upon the warm stove, they dissolved into a fluid which was perfectly as limpid as water, had an uncommonly strong, highly pungent, and almost suffocating acerous smell, and in the temperature of 145 of De Lisle's scale, immediately congealed into a solid white crystallized mass, resembling camphor.

The quantity of this excellent glacial vinegar amounted to two ounces; and the following are the most remarkable properties which it exhibits in this uncommonly beautiful crystallized state:

1. In a temperature of 145 degrees, the previously liquefied glacial vinegar begins to shoot into beautiful arborefcient and plumous figures, exactly in the same manner as water that undergoes a gradual congelation. There is at this time a considerable extrication of air-bubbles, and at length the vinegar congeals into a crystallized and completely solid mass.

2. This crystallized glacial vinegar requires a temperature of at least 126, in order to become fluid again.

3. The crystallization of the fluid glacial vinegar is soonest effected by placing it in water mixed with snow or ice.

4. If only a part of the crystallized glacial vinegar is melted, by the application of the warm hand, an appearance of very fine crystallizations is afforded, provided the warmth of the room is not greater than 136 degrees. This may be repeatedly produced. If it is suffered to remain undisturbed in this temperature, large specular crystals are seen to shoot up along the sides of the bottle, considerably above the fluid, and frequently to bend over to the opposite side, in the form of an arch, till they dip into the liquid vinegar again.

5. One of the most remarkable phenomena is this, that, by exposing to an increasing cold, a great variety of excessively delicate vegetations, resembling a sublimation, take place in the empty part of the bottle. Although they stretch out very far, and hang as it were floating in the empty part of the bottle, they only adhere by a very small point. They are so extremely thin and transparent, as not to be discernible in certain directions; and they frequently exhibit all the various colours of the rainbow.

6. By placing the melted glacial vinegar in snow, the four following equally pleasing appearances may be produced:

If, as exactly as possible, the smallest degree of cold in which the glacial vinegar is capable of beginning to freeze, be applied, there are immediately formed, on opening the bottle and shaking it a little, an immense number of extremely thin floating crystals, which are in the form of equilateral triangles, quadrangular planes, &c. and exhibit, especially in clear weather, the finest variety of colours.

On increasing the cold, and afterwards opening and shaking the bottle as before, beautiful, shining, thin crystals of a quadrangular, pentangular, hexangular, radiated form, fall to the bottom, and exactly resemble flakes of snow.

In a still greater degree of cold, little radiated balls, or globular lumps, fall down to the bottom, increasing very quickly in size during their descent.

Lastly, if the refrigeration is carried to its highest pitch, and the bottle is opened and shaken before the crystallization has spontaneously begun, the vinegar

negar congeals throughout, with an extraordinary quickness, into a compact, snow-white, striated mass.

For the production of these appearances, it is necessary that the glacial vinegar be previously brought into a perfectly liquid state.

7. The internal surface of the bottle, in which the glacial vinegar is kept, is frequently covered over with the finest delineated figures, some of which are crisped, after the manner of the frost on windows; others, on the contrary, are of an angular, jagged, or rectilinear form, amongst which are also sometimes to be seen, quite distinct from the other figures, equilateral triangles.

8. When the glacial vinegar begins to crystallize in a quiet place, the surface of the still fluid vinegar is covered over, as soon as some spicular and arborescent crystals shoot from the bottom upwards, with a crust as shining and smooth as a mirror; underneath which, however, a large concavity is immediately afterwards formed by the air, which is extricated in great abundance, and mounts upwards.

9. Glacial vinegar in its solid or crystallized state, notwithstanding the great quantity of air-bubbles that are entangled in its whole mass, occupies much less space than it did in its fluid state.

After Mr. Lowitz had attended to these striking properties, and had observed that vinegar in this state is of such an extraordinary strength and purity as to be in its highest degree of perfection, he took all possible pains to find out a method of obtaining all the acetous acid in the state of glacial vinegar.

The strength of each sort of vinegar, which it was necessary for him to know in his experiments, by degrees he ascertained in the following manner: viz. To one drachm of vinegar he added, drop by drop, a clear solution of equal parts of salt of tartar and water, till all at once a cloudiness or precipitation appears. Although, on the appearance of this sign, the acid is already super-saturated with the alkali, yet it seems to be a more accurate test for ascertaining its strength than the cessation of effervescence; for as the point of saturation approaches, the effervescence becomes so imperceptible, that it is almost impossible to determine with precision when it is really at an end. Every five drops of the alkaline solution, which he finds it necessary to add to the vinegar, till the precipitation takes place, he reckons as one degree. Thus, for example, if a determinate quantity of vinegar requires 25 drops for that effect, he denotes its strength by five degrees. This is about the strength of good distilled vinegar.

That vinegar which in consequence of its concentration is capable of crystallizing in a great degree of cold, he calls crystallizable vinegar; the crystals of vinegar separated after the crystallization is completed, from the remaining fluid portion, he calls glacial vinegar; and lastly, to the fluid residuum he gives the name of mother ley of vinegar.

From a great number of experiments he found, that vinegar must have at least twenty-four degrees of concentration, before it can be brought to crystallize by exposure to the most intense cold. Vinegar must be of the strength of 42 degrees at least, in order to become glacial vinegar; viz. in this state of concentration it has the property of crystallizing in a degree of cold not exceeding that in which water begins to freeze.

He found that charcoal, on being distilled with vinegar in a water-bath, possesses the singular, and hitherto unknown property, of imbibing a certain quantity of the acetous acid in a very concentrated state, and of retaining it so strongly,



strongly, that the acid cannot be separated from it again, but by the application of a considerably greater degree of heat than that of boiling water. Upon this circumstance is founded the new method which he discovered of concentrating vinegar, so as to obtain all its acid in the purest state, viz. that of a glacial vinegar.

Let a barrel of vinegar be concentrated by freezing in the manner before described, and let the concentrated vinegar thus obtained, free from all inflammable or spirituous parts, be put into two retorts: add to each of them five pounds of good charcoal reduced to a fine powder, and subject them to distillation in a water-bath. When no more drops of vinegar come over, put the distilled liquor into two fresh retorts; and after adding five pounds of charcoal powder to each, proceed, as before, to distillation in a water-bath. In the mean time, the two first retorts are to be placed in a sand-bath, that, by means of a brisk fire, the crystallizable vinegar which is retained in the apparently dry charcoal powder may be expelled from it. The heat must be strong enough to make the drops follow one another every two seconds; and when, in this degree of heat, 20 seconds intervene between each drop, the vinegar which has been collected must be removed; for what follows is hardly any thing else but mere water. In this manner about six ounces and a half of crystallizable vinegar, which is generally of the strength of between 36 and 40 degrees, may be collected from each retort. As soon as the distillation by the water bath in the two other retorts is over, the distilled liquor is to be poured back again into the first retorts upon the charcoal powder, which remains in them, and which has been already used; and from each of these retorts the remaining crystallizable vinegar (which generally amounts to as much as the first quantity) is to be abstracted by distillation in a sand-bath. These operations may be alternately repeated, till all the acid of the vinegar which had been concentrated by freezing, is converted into crystallizable vinegar; or until the distilled liquor, constantly becoming weaker and weaker at every repetition of the distillation, comes over at length in the state of mere water; which, with the abovementioned quantity of charcoal powder, generally happens at the fourth or fifth distillation. Now, in order to obtain the greatest part of the pure acid contained in the crystallizable vinegar, in the form of glacial vinegar, it must be set to crystallize in a great degree of cold; and the mother ley must be afterwards thoroughly drained from the glacial vinegar, by letting it drop from the crystals, first in the cold, and then in the room before the window. The mother ley may be rendered further crystallizable, by distilling it with a little charcoal powder; the weaker part which comes over first being put aside. But if a person wishes to keep the crystallizable vinegar (which far exceeds Mr. Westendorf's in point of strength) for other purposes, and without separating any glacial vinegar from it, he must distil the whole of it again with charcoal powder in a sand-bath.

Mr. Lowitz found by accurate experiments, that by means of this curious process ten pounds of vinegar concentrated by freezing to the nineteenth degree, may be made to yield 38 ounces of crystallizable vinegar, from which 20 ounces of glacial vinegar may be obtained.

What constitutes the excellence of this method, is, that the concentration and purification are effected by one and the same medium; viz. the charcoal powder; in consequence of which, both intentions are fulfilled at the same time.

The crystallization of the vinegar is, at the same time, the means by which it acquires its highest degree of concentration, and its greatest purity; for all the extraneous matter, which cannot otherwise be parted, even with the assistance of the charcoal, from the genuine acid, is thus separated from the pure acetous crystals, and left behind in the mother ley.

It was this extraneous matter, which cannot well be separated from the pure acetous acid by any other means but by crystallization, that led Dr. Amburger, agreeably to the results of his experiments, to draw conclusions contrary to Mr. Westrumb's theory, respecting the convertibility of the acetous acid into the acid of sugar.

Mr. Lowitz, in the course of his experiments relative to this process, for concentrating and purifying vinegar by charcoal powder and crystallization, made the following observations:

1. With one pound of charcoal powder very little more than ten drams of crystallizable vinegar are obtained; and this is the case, whether the vinegar, which is to be distilled over it, be strong or weak, in a large or in a small quantity. It is taken for granted, however, that the vinegar shall contain at least as much acid as the charcoal powder is capable of imbibing and retaining in the distillation by the water-bath.

2. The quantity of crystallizable vinegar which is obtained, is in a direct ratio to the quantity of charcoal powder employed.

3. The least cold in which crystallizable vinegar, prepared by means of charcoal powder, shoots into crystals, is that of 173 degrees.

4. In the first distillation a yellow crystallizable vinegar comes over; but in the subsequent distillations, by which the vinegar is purified from all its colouring or inflammable matter, it is always obtained perfectly limpid like water.

5. Crystallizable vinegar of the strength of 38 degrees, yielded glacial vinegar of 54 degrees of concentration, whilst the strength of the mother-ley amounted only to 28 degrees.

6. All glacial vinegar is not of an equal strength.

7. Mr. Lowitz thinks he has observed that glacial vinegar is stronger, in proportion to the intenseness of the cold by which it has been produced.

8. In a cold of 183 degrees, he obtained glacial vinegar of the strength of 54°, which he finds to be the highest degree of concentration which the acetous acid is capable of obtaining.

9. As the water-bath, though it insures success, is often inconvenient, and takes up a great deal of time, it may be dispensed with by a skilful management of the fire; which, however, requires very great attention.

Mr. Lowitz, in the further prosecution of the experiments with concentrated glacial vinegar, observed many other curious phenomena, which are as follow:

If vinegar concentrated by freezing be distilled very slowly, and without any addition, there comes over, at last, a small quantity of crystallizable vinegar, from which, by means of a great degree of cold, a little glacial vinegar may be procured. This method, however, is not only very tedious, but the vinegar thus obtained is highly phlogisticated and empyreumatic.

By abstracting a large quantity of common distilled vinegar, over charcoal powder, first in a water-bath and afterwards in a sand-bath, crystallizable vine-



gar may in like manner be obtained; but, on account of the great proportion of water in distilled vinegar, this method is extremely tedious.

Reflecting on this property of glacial vinegar, viz. that it requires for its liquefaction a degree of warmth considerably greater than that in which the completely liquefied glacial vinegar is capable of crystallizing, Mr. Lowitz was led to discover a method by which crystallizable vinegar may be made to crystallize in a cold 15 degrees less than that which was before required, viz. Into some previously liquefied glacial vinegar he dipped a thin cotton wick, crystallized the vinegar by placing it in snow, and then in a cold of 158 degrees applied the same wick, with the crystals adhering to it, to the surface of some crystallizable vinegar of the strength of 38 degrees; there immediately formed round the end of the wick a number of needle-shaped crystals, which visibly increased in size; the surface of the vinegar became covered over with an icy crust; a great number of radiated crystals, exactly resembling flakes of snow, gradually sunk to the bottom of the bottle, where they continued to accumulate, and at length the vinegar, throughout, shot into fine large crystals. By this mode of treatment, it is rendered unnecessary to wait for a cold of 173 degrees, so that we have it in our power, at all times, to obtain vinegar in the state of very beautiful transparent crystals, of a regular prismatic shape, and several inches in length.

From two pounds three ounces of perfectly dry soda acetata, and a pound and a half of highly concentrated oil of vitriol, Mr. Lowitz prepared, according to Mr. Westendorff's method, 13 ounces of an alcohol aceti, of the strength of 32 degrees. By exposing it in the night time to a cold of 174 degrees, and by applying to its surface some crystals of glacial vinegar, adhering to a cotton-wick, he immediately brought it to crystallize; and the next morning, in a cold of 182 degrees, he found it formed into beautiful prismatic crystals, which were three inches in length. After the mother ley was poured off, these crystals weighed three ounces two drams and a half. He distilled this mother ley, the strength of which still amounted to 24 degrees, with two pounds of charcoal powder, in a water-bath: the vinegar which came over into the receiver had a very sweet smell, and was now only of the strength of 16 degrees. From the residuous powder he afterwards obtained, by distillation in a sand-bath, two ounces six drams and a half of a smoking crystallizable vinegar, of the strength of 36 degrees.

The properties of this glacial vinegar, prepared from Mr. Westendorff's vinegar, are precisely the same as those of the glacial vinegar which is obtained by means of charcoal powder alone; whence it follows, that the vinegar is not altered by its combination with a foreign body (viz. the alkali), and its subsequent separation from it; or that the charcoal produces the same effect as the alkali.

After much reflection, Mr. Lowitz was so happy as to find out another very effectual method of separating the acetous acid from the other substances combined with it, so as to obtain it at once in the state of a glacial vinegar of the greatest possible strength. The separating medium which he thought of, is a vitriolated tartar super-saturated with vitriolic acid, a salt, in which, conformably to his purpose, the vitriolic acid exists in a perfectly dry and dephlegmated state.

His first business was to contrive an easy method of preparing this salt, whose properties have been hitherto but little examined; after various trials, he hit upon the following successful process:

Mix together in a tall matrass seven parts of water with an equal quantity of oil of vitriol, and to the very hot mixture add, as quickly as the effervescence will permit, four parts of salt of tartar, or levigated pot-ashes. As soon as the mixture becomes cool, the supersaturated vitriolated tartar shoots into fine large crystals. After the whole is become quite cold, and the crystallization is at an end, the liquor (which may serve again for a fresh mixture of the same kind) is to be poured off, and the salt which remains in the matrass is to be shaken together, and to be well rinsed as quickly as possible with cold water, in order to cleanse it from all the vitriolic acid which adheres to its surfaces, and which would otherwise be prejudicial to the dry acid. The crystals are afterwards to be dried by exposure to the fire, and to be triturated to a very fine powder, which, just before it is used, must be again thoroughly exsiccated.

By means of this salt, a highly concentrated glacial vinegar may be obtained in the following manner:

Let three parts of acetated soda, prepared with vinegar distilled over charcoal, and evaporated to perfect dryness, be melted in a strong heat; then pour it out, and rub it to a very fine powder. Mix this powder very accurately with eight parts of supersaturated vitriolated tartar, that has been previously well dried, and in like manner reduced to a fine powder; put the whole into a retort, and distil it with a gentle heat, in such a manner, that, along with the drops some vapours also may be perceived to come out of the neck of the retort; but by no means so that the receiver shall be filled with these vapours. Notwithstanding the moderate heat, the vinegar comes over very fast; and the quantity of glacial vinegar, of the strength of 54 degrees, which is thus obtained, amounts to nearly two parts, and possesses all the characters which have been before described.

By this process, seven pounds of glacial vinegar may be obtained from 300 pounds of common vinegar; and from five pounds of distilled vinegar, of the strength of five degrees, two ounces of glacial vinegar may be procured in the space of six hours.

This glacial vinegar generally acquires an unpleasant smell, from which, however, it may be completely freed by distillation with charcoal powder, in the proportion of at least five or six parts of the latter to one part of the vinegar; or, to three ounces of this vinegar add about a dram of perfectly dry and finely pulverized acetated calcareous earth; shake them well and repeatedly together, and let the mixture remain exposed to the sun-shine till the disagreeable smell is entirely gone; then re-distil the vinegar in a gentle heat.

In its purification, whatever be the way in which it is effected, this glacial vinegar is unavoidably lowered some degrees in strength.

The melting of the acetated soda only serves for the expulsion of all the watery parts from the salt; but a glacial vinegar of the strength of between 46 and 50 degrees may be procured from a merely exsiccated soda acetata.

For the production of glacial vinegar, by means of the supersaturated vitriolated tartar, not only the acetated mineral alkali, but also well dried acetated calcareous earth may be employed.

How much preferable this last process, with vitriolated tartar saturated with an excess of acid, is to the other, in which glacial vinegar is prepared from Mr. Westendorf's vinegar, will appear from a comparative statement of the following particulars:

1. In the direct separation by means of oil of vitriol, we are restrained from adding to the acetated salt as much of the vitriolic acid as is necessary for the ex-



pulsion of all the vinegar contained in the acetated soda, lest the required acetous acid should be too much debased by vitriolic or sulphureous acid : whereas, in the separation by means of the supersaturated vitriolated tartar, no harm at all can arise from adding an excess of the vitriolated salt, for the purpose of dislodging the whole of the vinegar contained in the acetated salt ; for the superfluous portion of vitriolic acid, combined with the alkali, adheres to it too strongly, and is too fixed in the fire, to be disengaged, and raised up by that gentle degree of heat which is sufficient for the separation of the acetous acid.

2. In the affusion of a very concentrated oil of vitriol upon the thoroughly dried acetated salt, we are far from being able to make the vitriolic acid penetrate the salt in an equal manner, which, however, is a matter of great consequence : whereas, in the trituration of the acetated salt with the supersaturated vitriolated tartar of Mr. Lowitz, the most equal commixture of both salts is readily effected.

3. During the affusion (though it be performed with the greatest caution) of highly concentrated oil of vitriol, a great heat is excited, whereby some of the vinegar is instantly consumed, a volatile sulphureous acid is produced, and part of the acetous acid is dissipated and lost in the form of vapour. But nothing of this kind takes place in Mr. Lowitz's last invented method : for there the salts do not begin to act reciprocally upon each other till the fire is applied.

4. The vinegar prepared according to Mr. Westendorf's method, always contains an admixture of vitriolic acid ; which, however, for the reason already assigned, is by no means the case with the glacial vinegar of Mr. Lowitz, provided the management of the fire is properly attended to.

5. Twenty-four ounces of acetated soda, treated with oil of vitriol, give only 12 ounces of a barely crystallizable vinegar, of the strength of 32 degrees, from which, at most, only six ounces of glacial vinegar can be procured. On the other hand, the same quantity of acetated soda (previously fused) treated with the supersaturated vitriolated tartar, yields nearly 16 ounces of glacial vinegar, of the strength of 54 degrees.

6. Glacial vinegar cannot be obtained from Mr. Westendorf's vinegar, except in winter, and by exposure to a very intense cold : but in the last described method of Mr. Lowitz, an exceedingly strong glacial vinegar may be immediately prepared at any time.

7. The supersaturated vitriolated tartar may be prepared from various pharmaceutical residua ; for instance, from the vitriolated tartar which remains after the purification of pot-ashes, and the residuum from the liquor anodynus ; and even the residuum, after the preparation of glacial vinegar by means of supersaturated vitriolated tartar, may, when the Glauber's salt which is produced is separated from it, be made to serve again, on the addition of fresh oil of vitriol, for another similar process.

A weak glacial vinegar may be concentrated in the following easy and at the same time entertaining manner :

Place the bottle containing the fluid glacial vinegar, which is to be concentrated, up to its neck in a vessel full of ice and water : in another quantity of previously concentrated glacial vinegar, surrounded in like manner with ice, dip a thin cotton-twist or wick ; as soon as some crystals are perceived to have attached themselves to the wick, apply the same to the surface of the glacial vinegar, which is to be concentrated, and it will be seen to shoot into considerably large crystals. In the course of an hour or two, let the weaker part which

still remains, be poured off, and the process repeated.

still remains fluid, be poured off, into another bottle, from the concentrated and crystallized glacial vinegar.

In winter this concentration of the glacial-vinegar may be effected in the following still more simple manner:

Pour the glacial vinegar, which is to be concentrated, into a glass bottle or jar with four sides; crystallize the vinegar by placing it in snow, or by exposure, in any other way, to cold; and then place it in a warm room, before the window (where, however, the rays of the sun are prevented from entering), in such a manner that one side of the bottle may come into close contact with the cold pane of the window. In the course of ten or twelve hours, the strongest part of the acid will arrange itself, in clusters of crystals, all along that side of the bottle which touches the pane of the window, whilst on the other side of the bottle which faces the room, the much weaker portion of the vinegar is found in a perfectly fluid state; so that all that remains to be done, is to pour off this fluid part into another bottle.

From the weaker portion that is separated in the concentration of the glacial vinegar, more glacial vinegar may yet be obtained, by exposure to cold, and more especially by means of the before-described process with the cotton wick: and even the still weaker mother ley, which remains at last, may very easily be brought to crystallize afresh, by the help of a gentle distillation.

Decisive experiments, and those frequently repeated, convinced Mr. Lowitz, that the 54th degree is the highest pitch of concentration to which glacial vinegar is capable of being brought. Notwithstanding all the pains he took, he never was able either by distillation, or by any of the other concentrating methods already mentioned, to push the concentration of glacial vinegar even a single degree farther; on the contrary, the vinegar was rendered weaker by some degrees in all such attempts.

The reason of this seems to be, that the acetous acid, like some of the mineral acids, when still further dephlegmated, or deprived of its watery parts, is no longer capable of remaining in a condensed state, but probably assumes an aerial or gaseous form; otherwise, in the further abstraction of its watery parts, how could there be such a constant diminution of its strength, evidently owing to a loss of acid?

Upon this principle we can easily account for the extraordinary quantity of air bubbles, which are produced as often as the glacial vinegar passes from the fluid to the solid crystallized state. The white appearance of the crystals depends on the same cause.

Hence, too, we see the impossibility of having a glacial vinegar, which shall retain its solid crystallized form during summer, unless it be kept in a place where the warmth never exceeds, at most, 126 degrees. Thus, for example, in a cellar whose temperature remains constantly at 131 degrees, summer and winter, a strong glacial vinegar would never become fluid; but if the same vinegar should be brought into this cellar in a perfectly liquefied state, it would never crystallize there, on account of the difference between the temperature required for the crystallization, and that which is necessary for the liquefaction of glacial vinegar.

By very accurate experiments Mr. Lowitz found, that the least cold which suffices, without the application of ice or snow, for the crystallization of a perfectly fluid glacial vinegar of the strength of 54 degrees, is that of 132 degrees. All that is needful is, after letting the glacial vinegar stand

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some time in water of the above mentioned temperature, to open the bottle, and shake it a little so that the external air may enter, and have free access to the vinegar.

Lastly, we may at all times obtain glacial vinegar in a crystallized form, by means of an artificial cold; viz. Pour the vinegar into a thin slender bottle, wrap round this some rag moistened with a little rectified vitriolic æther, and whirl it about briskly in the air.

It is a circumstance worthy of notice, that the weakest glacial vinegar, in respect to the quantity of alkali necessary to its saturation, is stronger than the strongest smoking spirit of nitre. On this test however see **ATTRACTION**, p. 164.

**VIRGULA DIVINATORIA.** See **ROD**, **DIVINING**.

**VITAL AIR.** See **AIR**, **VITAL**.

**VITRIFICATION.** See **GLASS**, also **SILEX**.

**VITRIOL.** The saline combination of copper with the vitriolic acid is called blue vitriol, in commerce. Vitriolic acid and iron form green vitriol, or the green copperas of the shops. Vitriol of zinc is called white copperas. The looseness and inaccuracy of these denominations are evident. Some chemists have endeavoured to generalize the term vitriol, by applying it to all combinations containing vitriolic acid. Thus they would say, vitriol of iron, or of copper, or of lime; but this method has never been generally adopted. It is usual however to call all the metallic salts vitriols, which contain vitriolic acid. See **ACID**, **VITRIOLIC**; **SULPHUR**; **PYRITES**, and the several **Metals**.

**VITRIOLIC ACID.** See **ACID**, **VITRIOLIC**.

**VOLATILE ALKALI.** See **ALKALI**, **VOLATILE**.

**VOLATILITY.** That property of bodies by which they are disposed to assume the vaporous or elastic state, and quit the vessels in which they are placed. In many instances of chemical operation, the most simple substances are found to be the most volatile, and many principles are rendered more fixed by combination. This is the most general observation; but there are a number of instances in which volatility follows from combination, though for the most part less in degree than was possessed before by the more volatile of the matters so combined. Of all substances known the earths are the least volatile, next to these are some of the metals, and these are followed by the fixed alkalis and a few of the acids. All other bodies possess considerable volatility.

**VOLCANOS** \*. The combustion of those enormous masses of bitumen which are deposited in the bowels of the earth, produces volcanos. They owe their origin more especially to the strata of pyritous coal. The decomposition or action of water upon the pyrites determines the heat, and the production of a great quantity of inflammable air, which exerts itself against the surrounding obstacles, and at length breaks them. This effect appears to be the chief cause of earthquakes; but when the concurrence of air facilitates the combustion of the bitumen and the inflammable air, the flame is seen to issue out of the chimneys or vents which are made: and this occasions the fire of volcanos.

There are many volcanos still in an active state on our globe, independent of those of Italy, which are the most known. The Abbé Chappe has described three burning in Siberia. Anderson and Von Troil have described those of Iceland. Asia and Africa contain several: and we find the remains of these fires or volcanic products in all parts of the globe.

\* Chaptal, Elem. ii. 221.

Naturalists inform us that all the southern islands have been volcanized; and they are seen daily to be formed by the action of these subterraneous fires. The black colour of the stones, their spongy texture, the other products of fire, and the identity of these substances with those of the volcanos at present burning, are all in favour of the opinion that their origin was the same.

When the decomposition of the pyrites is advanced, and the vapours and elastic fluids can no longer be contained in the bowels of the earth, the ground is shaken, and exhibits the phenomena of earthquakes. Mephitic vapours are multiplied on the surface of the ground, and dreadful hollow noises are heard. In Iceland, the rivers and springs are swallowed up; a thick smoke mixed with sparks and lightning is then disengaged from the crater; and naturalists have observed that, when the smoke of Vesuvius takes the form of a pine, the eruption is near at hand.

To these preludes, which shew the internal agitation to be great, and that obstacles oppose the issue of the volcanic matters, succeeds an eruption of stones and other products, which the lava drives before it; and lastly, appears a river of lava, which flows out, and spreads itself down the side of the mountain. At this period the calm is restored in the bowels of the earth, and the eruption continues without earthquakes. The violent efforts of the included matter sometimes cause the sides of the mountain to open; and this is the cause which has successively formed the smaller mountains which surround volcanos. Montenuovo, which is a hundred and eighty feet high, and three thousand in breadth, was formed in a night.

This crisis is sometimes succeeded by an eruption of ashes which darken the air. These ashes are the last result of the alteration of the coals; and the matter which is first thrown out is that which the heat has half vitrified. In the year 1767, the ashes of Vesuvius were carried twenty leagues out to sea, and the streets of Naples were covered with them. The report of Dion, concerning the eruption of Vesuvius in the reign of Titus, wherein the ashes were carried into Africa, Egypt, and Syria, seems to be fabulous. Mr. de Saussure observes that the soil of Rome is of this character, and that the famous catacombs are all made in the volcanic ashes.

It must be admitted, however, that the force with which all these products are thrown is astonishing. In the year 1769, a stone twelve feet high and four in circumference, was thrown to the distance of a quarter of a mile from the crater: and in the year 1771, Sir William Hamilton observed stones of an enormous size, which employed eleven seconds in falling. This indicates an elevation of near two thousand feet.

The eruption of volcanos is frequently aqueous: the water, which is confined, and favours the decomposition of the pyrites, is sometimes strongly thrown out. Sea salt is found among the ejected matter, and likewise sal ammoniac. In the year 1630, a torrent of boiling water, mixed with lava, destroyed Portici and Torre del Greco. Hamilton saw boiling water ejected. The springs of boiling water in Iceland, and all the hot springs which abound at the surface of the globe, owe their heat only to the decomposition of pyrites.

Some eruptions are of a muddy substance; and these form the tufa, and the puzzolano. The eruption which buried Herculaneum is of this kind. Hamilton found an antique head, whose impression was well enough preserved to answer the purpose of a mould. Herculaneum at the least depth is seventy feet under the surface of the ground, and often at one hundred and twenty.

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The puzzolano is of various colours. It is usually reddish; sometimes grey, white, or green: it frequently consists of pumice stone in powder; but sometimes it is formed of calcined clay. One hundred parts of red puzzolano afforded Bergman, silic 55, alumine 20, lime 5, iron 20.

When the lava is once thrown out of the crater, it rolls in large rivers down the side of the mountain to a certain distance, which forms the currents of lava, the volcanic causeways, &c. The surface of the lava cools, and forms a solid crust, under which the liquid lava flows. After the eruption, this crust sometimes remains, and forms hollow galleries, which Messrs. Hamilton and Ferber have visited: it is in these hollow places that the sal ammoniac, the marine salt, and other substances, sublime. A lava may be turned out of its course by opposing banks or dykes against it: this was done in 1669, to save Catania; and Sir William Hamilton proposed it to the king of Naples to preserve Portici.

The currents of lava sometimes remain several years in cooling. Sir William Hamilton observed, in 1769, that the lava which flowed in 1766 was still smoking in some places.

When the current of lava is received by water, its cooling is quicker; and the mass of lava shrinks so as to become divided into those columns which are called basaltæ. The famous Giant's Causeway is the most astonishing effect of this kind which we are acquainted with. It exhibits thirty thousand columns in front, and is two leagues in length along the sea coast. These columns are between fifteen and sixteen inches in diameter, and from twenty-five to thirty feet long.

The basaltæ are divided into columns of four, five, six, and seven sides. The emperor Vespasian made an entire statue, with sixteen children, out of a single column of basaltæ, which he dedicated to the Nile, in the Temple of Peace.

Basaltæ afforded Bergman, per quintal, silic 56, alumine 15, lime 4, iron 25.

Lava is sometimes swelled up and porous. The lightest is called pumice-stone.

The substances thrown out by volcanos are not altered by fire. They eject native substances, such as quartz, crystals of amethyst, agate, gypsum, amianthus, felt-spar, mica, shells, schorl, &c.

The fire of volcanos is seldom strong enough to vitrify the matters it throws out. We know only of the yellowish capillary and flexible glass thrown out by the volcanos of the island of Bourbon, on the 14th of May 1766 (M. Commerçon), and the lapis gallinaceus ejected by Hecla. Mr. Egelström, who is employed by the observatory at Copenhagen, has settled in Iceland, where he uses a mirror of a telescope which he has made out of the black agate of Iceland.

The slow operation of time decomposes lavas, and their remains are very proper for vegetation. The fertile island of Sicily has been every where volcanized. Chaptal observed several ancient volcanos at present cultivated; and the line which separates the other earths from the volcanic earth, constitutes the limit of vegetation. The ground over the ruins of Pompeia is highly cultivated. Sir William Hamilton considers subterranean fires as the great vehicle used by nature, to extract virgin earth out of the bowels of the globe, and repair the exhausted surface.

The decomposition of lava is very slow. Strata of vegetable earth, and pure lava, are occasionally found applied one over the other; which denote eruptions made

made at distances of time very remote from each other, since it requires nearly two thousand years before lava receives the plough. An argument has been drawn from this phenomenon to prove the antiquity of the globe: but the silence of the most ancient authors concerning the volcanos of the kingdom of France, of which we find such frequent traces, proves that these volcanos have been extinguished from time immemorial; a circumstance which carries their existence to a very distant period. Besides this, several thousand years of connected observations have not afforded any remarkable change in Vesuvius or Etna; nevertheless these enormous mountains are all volcanized, and consequently formed of strata applied one upon the other. The prodigy becomes much more striking, when we observe that all the surrounding country, to very great distances, has been thrown out of the bowels of the earth.

The height of Vesuvius above the level of the sea, is three thousand six hundred and fifty-nine feet; its circumference, thirty-four thousand four hundred and forty-four. The height of Etna is ten thousand and thirty-six feet; and its circumference one hundred and eighty thousand.

The various volcanic products are applicable to several uses.

1. The puzzolano is of admirable use for building in the water: when mixed with lime it speedily fixes itself; and water does not soften it, for it becomes continually harder and harder. Chaptal has proved that calcined ochres afford the same advantage for this purpose; they are made into balls, and baked in a potter's furnace in the usual manner. The experiments made at Sette, by the commissary of the province, prove that they may be substituted with the greatest advantage instead of the puzzolano of Italy.

2. Lava is likewise susceptible of vitrification; and in this state it may be blown into opaque bottles of the greatest lightness, which Chaptal says he has done at Erebian and at Alais. The very hard lava, mixed in equal parts with wood-ashes and soda, produced, says he, an excellent green glass. The bottles made of it were only half the weight of common bottles, and much stronger; as was proved by Chaptal's experiments, and those which Mr. Joly de Fleury ordered to be made under his administration.

3. Pumice-stone likewise has its uses; it is more especially used to polish most bodies which are somewhat hard. It is employed in the mass or in powder, according to the intended purpose. Sometimes, after levigation, it is mixed with water to render it softer.

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**ULTRAMARINE.** A blue colour, made from lapis lazuli. The manipulations for making it are variously described by authors, and consist in pulverizing the stone very finely, by ignition, quenching it in water, and subsequent levigation. This powder is then carefully stirred by small portions



tions at a time into a mass of resinous composition, from which it is again extracted by washing and kneading in hot water. Some artists use the mere powder of lapis lazuli without any subsequent management.

I find it difficult to form an opinion as to what happens in this process, which seems to be merely of a mechanical nature. Whether it differs at all from simple elutriation and subsidence, by which the finer parts of powders are separated from their coarser parts; and if so, in what respect, are questions which demand the test of experiment. What may be the use of the resinous compound? Do the parts of the finest colour adhere less forcibly to the resin, and are therefore washed out first? It seems hardly probable, more especially if, as Neri \* informs us, the same process may be applied to blue enamel, by which I suppose he means glass tinged with cobalt.

Kunckel † describes a process which he says was successful in his hands; and though upon perusal it seems capable of being much simplified, I shall give it unaltered in this place, because at least as simple as any of the other receipts.

Lapis lazuli was reduced to pieces about the size of peas, then ignited and extinguished in stronger vinegar. The author says, distilled vinegar is preferable. The stone was in the next place triturated with vinegar to an impalpable powder. This is said to be the most important part of the operation. Of a composition of equal parts very pure virgin wax and colophony, a quantity was taken of the same weight as that of the powdered stone. This was melted in a glazed earthen plate, and the powder was added by a little at a time, and well stirred in. The mass was then poured into cold water and left for eight days, at the end of which, two vessels of glass were filled with water so hot as barely to suffer the hand to be plunged in it. A piece of the composition was then kneaded under water till it was supposed that the finest part of the colour was extracted. The mass was then transferred to the other water, and afforded a paler and less valuable blue than the first. The waters were left at rest for four days and then decanted off, and the powder carefully collected. The quantity of the best blue is very small; but the same mass, by kneading in different waters, especially when the quantity operated upon is large, affords three or four different kinds. Cleanliness of the hands, and of all the vessels and materials made use of, is of the utmost consequence in the manufacture.

**UMBER.** A brown ochreous earth used as a pigment. It acquires a reddish colour when slightly heated, but in a stronger heat becomes again brown, and magnetic, and in a still stronger is fused into a black glass. It does not effervesce with acids before roasting, but after that process the iron it contains is soluble.

Kirwan also mentions under this name, in his Argillaceous Genus, a brown or blackish substance which stains the fingers, and is very light. This was long supposed to be a clay; but M. Hupsch, in the Berlin Memoirs for 1777, shews that it consists of particles of decayed wood mixed with bitumen.

**UNION.** This word is often used by chemists to denote the combination of principles, or rather their co-existence in any compound. Thus it is said that the parts of a mere mixture are united mechanically; but in an actual combination they are said to be chemically united.

**URANITE, or URANIUM.** A new metallic substance discovered by the celebrated Klaproth in the mineral called *Pech blende*; which see.

\* L'Art de la Verrerie, 239.

† Loc. cit. 240.

**URINE.** This excrementitious fluid, in its natural state, is transparent, of a yellow colour, a peculiar smell and saline taste. Its production as to quantity, and in some measure quality, depends on the seasons and the peculiar constitution of the individual. It is observed, that perspiration carries off more or less of the fluid, which would else have passed off by urine; so that the profusion of the former is attended with a diminution of the latter.

From the alkaline smell of urine kept for a certain time, and other circumstances, it was formerly supposed to be an alkaline fluid; but Berthollet has shewn that it contains an excess of phosphoric acid. He found likewise that the urine of gouty patients contains a less quantity of this excess; whence he rationally conjectures that the acid retained in the blood, and conveyed through the system, must produce irritation, pain, and other bad consequences.

Many chemists have analysed urine by distillation. Much phlegm comes first over, which speedily putrefies; and this affords volatile alkali, though it shews no signs of that principle in its fresh state. At the same time a substance of an earthy appearance falls down from the urine, which consists of phosphorated lime, with the acid of the stone of the bladder. *Salts of urine* are separable by evaporation and cooling, which is the usual method, as the phlegm is of no value. They consist, for the most part, of two salts; the one formed of phosphoric acid and mineral alkali, and the other of the same acid with volatile alkali. Besides these salts, and the phosphorated lime which appears to be suspended by virtue of the excess of acid, urine contains the common salt taken with our food, and a portion of such other saline matters as may occasionally have been taken.

The salts obtained by evaporation and crystallization from urine, are clogged with a thick mucilaginous matter, of which they may be deprived by solutions in water and evaporation. In these processes, however, it is observed, that the product of crystals is greatly diminished if the solution, filtration, and cooling, be prepared in open vessels. A close apparatus of tin may be used for this purpose. Two strata of salt are then obtained, the upper of which has the form of square tables, and is phosphorated mineral alkali; and beneath this lies another salt crystallized in regular tetrahedral prisms, which is phosphorated volatile alkali. Bergman seems, in his blow-pipe experiments, to have used these salts under the denomination of microcosmic salt, in the proportion they are obtained together from urine. It is probable that after all the modern discoveries relative to PHOSPHORUS, and the Acid of PHOSPHORUS, most chemists will prefer making them by direct combination of the acid and alkalis respectively, or by the process of M. Giobert, instead of the less easy and unpleasant method here mentioned.

The mucilaginous residue, or mother water of urine after the crystallization of salts, is partly soluble in ardent spirit. This portion, which appears to possess the saponaceous state, is susceptible of crystallization, but is deliquescent. By destructive distillation it affords upwards of half its weight of mild volatile alkali, a little oil, and some sal ammoniac. Its residue reddens syrup of violets. Scheele has discovered that the volatile alkali in this matter is combined with acid of benzoïn, which separates when vitriolic or marine acid is added to the aqueous solution. *Crell's Journal, English, ii. 19.*

Water takes up an extractive matter from the mother water of urine. This is not soluble in ardent spirit, is easily dried, and very little disposed to attract

6 N 2 . moisture.



moisture. Its products by distillation are the same as those of animal matters in common.

The urine usually spoken of by chemists is that which has passed the process of digestion. The clear urine which passes off immediately after meals, is distinguished by the name of crude urine, and contains a very small portion either of saline or extractive matter. It is thought from various circumstances, particularly its speedy passage, to be transmitted by filtration from the stomach and intestines, through the cellular membranes directly to the bladder.

The spontaneous change or putrefaction of urine is attended with distinct phenomena, which have been enumerated and described by Mr. Hallé, in the Memoirs of the Society of Médecine at Paris, for 1779. The colouring matter subsides, volatile alkali flies off, and the predominating acid is in some instances greatly increased. The alkaline smell is succeeded in course of time by another much more nauseous. Various depositions are thrown down, and crystals separated, which it does not appear from Fourcroy, whose Elements I follow in this reference, that M. Hallé examined chemically.

Quicklime and the alkalis decompose the salts of urine; and the disengaged volatile alkali flying off in an impure state, instantly exhibits a strong unpleasant smell. Volatile alkali added to fresh urine saturates the excess of acid, and by that means causes the phosphoric salt of lime, which was materially suspended by that excess, to fall down. Hence, as Berthollet remarks, the quantity of disengaged acid, or its proportions, may be ascertained from the weights of the precipitates thrown down.

Acids produce no obvious change in fresh urine; but they speedily deprive putrid urine, or its sediment, of their smell. There is little doubt but they do this by neutralizing the volatile alkali.

Many metallic solutions are decomposed in the way of double affinity by urine; the solvent of the metal seizing the alkalis of the urinous salts, and the phosphoric acid uniting with the neutral, most commonly in an insoluble compound. See PHOSPHORUS, p. 655; also PRECIPITATE, ROSE-COLOURED.

Concerning the acid matter which appears to be the chief component part of the stone, or urinary calculus, see STONES, or CALCULI, found in the bodies of animals.

## W

### W A D

### W A L

**WADD.** This name is given to plumbago or black lead.

**WADD BLACK.** An ore of manganese found in Derbyshire. It is remarkable for the property of taking fire when mixed with linseed oil. See P. 597.

**WALKLERA.** The Swedish name for a grey stone marrow. The word signifies Fuller's earth.

**WAND.** See **ROD, DIVINING.**

**WASHING.** See **ELUTRIATION**; also **TIN**, p. 940.

**WATER.** It is scarcely necessary to give any definition or description of this universally known fluid. It is a most transparent fluid, possessing a moderate degree of activity with regard to organized substances, which renders it friendly to animal and vegetable life, for both which it is indeed indispensably necessary. Hence it acts, but slightly on the organs of sense, and is therefore said to have neither taste nor smell. It appears to possess considerable elasticity, and yields in a perceptible degree to the pressure of air in the condensing machine, as Canton proved, by including it in an open glass vessel with a narrow neck. This condensation is proportioned to the pressure, and it recovers its original dimensions when the force is removed. The same elastic force is shewn by the rebounding of stones or bullets, which strike the surface of water obliquely, as is seen in the diversion of boys, which in this country they call making ducks and drakes. A flat stone is thrown from the hand, nearly in an horizontal direction, with its surface parallel to that of the water, upon which it passes, by repeated bounds, with nearly the same facility as if the water were frozen; till at last the force of projection being expended, it sinks. The musical sonorousness of water passing in certain circumstances among pebbles, is another proof of its elasticity, and perhaps the slight adhesion of its particles.

Water does not possess any considerable density. Most mineral substances are heavier than this fluid, and among organized matters, there are perhaps none, except oils, and the products of art, which if lighter than water do not owe this property to their mechanical structure. At a moderate temperature water assumes the solid state, or freezes; and at a degree of heat far below that required to fuse any of the simple metals but mercury, its internal parts assume the elastic state, and fly off with ebullition. The freezing and boiling points of water are assumed as the standards for admeasurements of heat. See **THERMOMETER**, also **HEAT**. Its weight also is used as the standard for specific gravities; see **GRAVITY, SPECIFIC**; also **SPIRIT, ARDENT**. Its capacity for heat is taken as the standard of the specific heats of bodies. And in a word, the solubility or insolubility of bodies in this fluid composes a large part of the science of chemistry.

When water is cooled gradually, it contracts in its dimensions till within 8° of freezing, and then expands till it begins to assume the solid state. Congealed water or ice is considerably larger in its dimensions than water, upon which it therefore floats. The expansion of ice, at the time of its formation, is made with such force as to burst the strongest metallic vessels. The assumption of the solid state in water is effected, like other crystallizations, under a symmetrical figure. The parts which become solid first by freezing, have the form of daggers crossing each other at angles of 60 degrees. The crystallization of ice is also seen to advantage in snow and hoar frost, which are of the nature of the vegetation of salts, though probably they may not require the co-operation of light.

Steam, or the vapour of water, possesses a strong power of expansion, which is greater the higher its temperature. This power has within the last century been very advantageously applied to mechanical purposes. The vapour of water is more expandible in the same weight and temperature than air; whence the steam in half-filled vessels always occupies the upper place, and moist air is less



less heavy than dry. Common air imbibed by water, and afterwards expelled again, is found to contain somewhat more of vital air than before. It follows therefore, that the vital part of the atmosphere is more disposed to combine with water than the azotic part. This effect is remarkably perceived in fogs, which commonly exhibit the peculiar smell of burned gunpowder or azotic air; and must be ascribed to a proportion of the vital air having combined with the water of the fog.

The eolipile is a copper vessel, or globe, with a small aperture on one side. If this be heated and then immersed in water, it will be partly filled by the pressure of the atmosphere; and if this water be then made to boil, the steam will issue out with considerable violence, and excite a fire in the same manner as bellows. This has been thought to indicate a decomposition of the water; but it is not the steam which produces this effect, but the air it carries with it by its mechanical impulse; for if the nozzle of an eolipile be inserted directly into the fire, without leaving any space for the interposition of a body of air, it will not excite but extinguish the fire, as Dr. Lewis proved by experiment.

Water is not only the common measure of specific gravities, but the tables of this element (see p. 366) may be usefully employed in the admeasurement of irregular solids; for one cubic foot is very nearly equal to 1000 ounces avoirdupois. The numbers of the table denoting the specific gravities, do therefore denote likewise the number of ounces avoirdupois in a cubic foot of each substance.

Native water is seldom, if ever, found perfectly pure. The waters that flow within, or upon the surface of the earth, contain various earthy, saline, metallic, vegetable, or animal particles, according to the substances over or through which they pass. Rain and snow waters are much purer than those, although they also contain whatever floats in the air, or has been exhaled along with the watery vapours. Margraaf has analysed by gentle distillation some clear rain and snow waters that he had very carefully collected in glass vessels. The several residuums obtained by distilling a hundred measures of rain water, each of which contained thirty-six ounces, he distilled and evaporated, till no more remained than six or eight ounces of water, which was very turbid. From this remainder he obtained by filtration, a hundred grains of a yellowish white calcareous earth; and the filtrated liquor still contained some earthy particles suspended in it. Upon adding some drops of a solution of salt of tartar to this filtrated liquor, he obtained by evaporation a few grains of crystals, which had the appearance of nitre and common salt. From these crystals he inferred, that the rain water contained a small portion of nitrous and marine acids; and from the colour of the crystals, which was brownish, he concludes that it also contained some oil and viscous particles. He further proved the presence of marine acid in rain water, by adding a concentrated residuum of distilled rain to solutions of silver, mercury, and lead, in nitrous acid; from all which solutions precipitates were thereby formed. He discovered the earthy, saline, mucilaginous, and oily principles, by exposing rain water to the rays of the sun, during some months, in a glass vessel covered so as to exclude the dust, but not air; by which means the water underwent a kind of fermentation or putrefaction, and a greenish slime was formed on the sides and bottom of the containing vessel. This fermentation he found could not be excited by treating in the same manner the rain water that had passed over in the distillation made in order to procure the above-mentioned residuum.

Margraaf

Margraaf having treated a hundred measures of snow water in the same manner as he had done the rain water, obtained sixty grains of a similar white calcareous earth, together with the same saline, mucilaginous, and oily principles, but observed that the rain water contained a larger proportion of the nitrous acid, and the snow water more of the marine acid. Upon a further examination of the calcareous earths obtained from rain and snow, he discovered that they contained a ferruginous matter.

The purity of water may be known by the following marks or properties of pure water:

1. Pure water is lighter than water that is not pure; for not only the substances usually dissolved in water are heavier than water, but also the specific gravity of a solution of any of these substances in water is generally greater than the intermediate specific gravity of the water and of that substance.

2. Pure water is more fluid than water that is not pure; hence it is said to occasion a louder sound when poured from one vessel into another.

3. It has no colour, smell, or taste.

4. It wets more easily than the waters containing metallic and earthy salts, called hard waters, and feels softer when touched.

5. Soap, or a solution of soap in spirit of wine, mixes easily and perfectly with it.

6. It is not rendered turbid by adding to it a solution of gold in aqua regia, or a solution of silver, or of lead, or of mercury, in nitrous acid, or a solution of sugar of lead in water.

Boerhaave, Macquer, and other chemists, maintain, that pure water is unalterable; and others, as Borichius, Boyle, Wallerius, that it may be decomposed or resolved into other principles, especially into earth.

Boyle relates, that one ounce of water, distilled carefully in glass vessels two hundred times, yielded six drams of a white, light, insipid earth, fixed in the fire, and indissoluble in water. Boerhaave attributed the earth obtained by distillation of water, to dust floating in laboratories. Other chemists have made experiments to ascertain the truth of that of Boyle. Liedenfrost found, that when pure distilled water is dissipated or evaporated by throwing it into a red hot iron spoon, he always obtained a quantity of earth. Wallerius obtained a scruple and a half of fine white earth by triturating during two hours a dram of distilled water. This earth, he says, is soluble in acids, is convertible into a hard mass by a red heat, which mass is unsoluble by acids, and is vitrifiable into a white transparent glass by a more violent heat. He found also, that a larger quantity of earth is deposited from boiling water with a strong, than with a gentle fire. See the Swedish Memoirs for the year 1760. Margraaf has made experiments with his accustomed accuracy, from which it appears, that by distillation, and also by evaporation with the heat of the sun, of rain water, the purity of which had been previously ascertained by thirteen distillations, he obtained a white, light, shining earth. This earth could not be vitrified with the heat requisite for the fusion of ordinary glass; but by a more violent and longer continued fire it was melted into a yellow greyish mass. He found, that about half of this earth was soluble in nitrous acid, and that the other half was not fusible by fire; but that, by addition of half its quantity of salt of tartar, it was convertible into a transparent glass. The part of the earth that was dissolved in nitrous acid, was afterwards precipitated from that acid by vitriolic acid, with which it formed a selenites; and hence Margraaf infers, that it is a

true



true calcareous earth. He does not determine the class of earths to which the insoluble part of the earth thus obtained by distilling water ought to be referred. Margraaf observes, that earth is more copiously deposited from water boiling with a strong than with a gentle heat. The quantity of earth that he obtained, in one experiment, from seventy-two ounces of distilled water, by twelve distillations, was nine or ten grains.

Lavoisier however maintains, that the earth thus obtained by distilling water proceeds from the vessels employed; and the experiments of Scheele appear to have decided that it is so. See his Treatise on Air and Fire.

Margraaf obtained earth from water by another experiment. He put two ounces of distilled water into a glass vessel ten inches high, and from one to two inches in diameter, and closed the mouth with a smooth glass stopper. After the water had been agitated up and down in this tube eight days, it was observed to be turbid; and upon continuing the agitation eight days longer, he observed distinctly, especially upon exposing the tube to the rays of the sun, particles of earth floating in the water.

The action of water upon various saline substances, or their respective solubilities, constitutes an object of great value in the science of chemistry. This has been occasionally shewn under the respective articles. But as these results may be of value seen all together, I shall here insert three tables from the Notes on Macquer's Dictionary.

The following Table shews the quantities of the saline substances that could be dissolved in an ounce of water, with the heat of 50° of Fahrenheit's scale, according to experiments made by Mr. Spielman. Instit. Chémia, p. 48.

	Grains		Grains
Terra foliata Tartari	470	Salt of Seignette	137
Salt of Sedlitz	384	Blue Vitriol	124
Epsom Salt	324	Green Vitriol	80
Salt of Tartar	240	Purified Nitre	60
Vegetable Salt	212	Sal Polychrest of Glafer	40
White Vitriol	210	Vitriolated Tartar	30
Sal Gem	200	Sublimate Mercury	30
Salt of Soda	200	Borax	20
Sal Ammoniac	176	Alum	14
Common Salt	170	Volatile Salt of Amber	5
Salt of Glauber	168	Arsenic	5
Salt of Lorraine	168	Crude Tartar	4
Salt of Sylvius	160	Cream of Tartar	3

The following Table is copied from Muschenbroek. The eight first experiments were made by Boerhaave, and the rest by Muschenbroek, with a heat of 38°.

Sea Salt	oz. 2	were dissolved in	oz. 6 and dr. 3	of pure water
Sal Gem	oz. 1		oz. 3 and dr. 2	
Sal Ammoniac	oz. 1		oz. 3 and dr. 2	
Nitre	dr. 9		oz. 6	
Borax	dr. 4		oz. 10	
Alum	oz. 1		oz. 14	
Epsom Salt	oz. 1		oz. 1 and dr. 2	
Green Vitriol	dr. 1½		oz. 3	

Arsenic

Arsenic oz. 1 were dissolved in oz. 30  
 Blue Vitriol gr. 50 gr. 850  
 Salt of Hartshorn gr. 50 gr. 765  
 Sugar of Lead gr. 50 gr. 595  
 Salt of Tartar gr. 50 gr. 85  
 Glass Gall gr. 50 oz. 7½  
 Cream of Tartar gr. 50 oz. 1000 of boiling water  
 Fifty grains of cream of tartar may be dissolved in 100 grains of lime water.  
 Hist. de l'Acad. Royale, 1732.

Sugar of milk, dr. 7. were dissolved in lb. 1. of water, heated to the 167°.

According to Neumann's experiments, the quantities of salts soluble in an ounce of water are expressed in the following Table. He does not mention the heat employed. It was probably between 50° and 60°.

White powd. Sugar	oz. 2	Blue Vitriol	dr. 2
Brown powd. Sugar	oz. 2	Pure Nitre	dr. 1 gr. 10
White or brown Sugar		Sal Prunell	dr. 1
Candy	dr. 9	Soluble Tartar	dr. 1
Sal Diureticus	oz. 1	Alum	scr. 2½
Epſom Salt	oz. 1	Sal Polychrest	scr. 2
Sedlitz Salt	dr. 6	Arcaſum Duplicatum	dr. ½
Pure fixed Alkali	dr. 6	Vitriolated Tartar	dr. ½
White Vitriol	oz. ½	Sugar of Milk	scr. 1
Martial Vitriol	oz. ½	Sugar of Lead	scr. 1
Sal Gem	dr. 3 scrup. 1	Emetic Tartar	scr. 1
Sea Salt	dr. 3	Borax	gr. 15
Salt of Glauber	dr. 2	Salt of Sorrel	gr. 10
Sal Ammoniac	dr. 2	White Tartar	gr. 5
Volatile Sal Ammoniac	dr. 2	Cryſtals of Tartar	gr. 5
Potaſh	dr. 2		

Water when ſaturated with one ſalt is capable of diſſolving a conſiderable portion of another ſalt; and when ſaturated with this alſo, it may ſtill diſſolve a third, a fourth, or more ſalts. Thus, according to Neumann, four ounces of water that have been ſaturated with a dram and a few grains of alum, will ſtill diſſolve five drams of nitre, then half an ounce of green vitriol, fix drams of common ſalt, three drams of ſoluble tartar, and five drams of ſugar. In the ſame manner alſo, four ounces of water ſaturated with half an ounce of nitre, will diſſolve half an ounce of white vitriol, fix drams of common ſalt, fix drams of ſal ammoniac, half an ounce of ſoluble tartar; and after all theſe an entire ounce of ſugar.

Mr. Eller has published an account of the following experiments concerning the ſolutions of different ſalts in the ſame water. See Mem. of the Acad. of Berlin for the year 1730.

In each experiment, he employed eight ounces of diſtilled water. He found that this quantity of water, when ſaturated

With four ounces of nitre, diſſolved one ounce five drams of fixed alkali, and half an ounce of common ſalt.

With three ounces one dram and one ſcruple of common ſalt, diſſolved three drams of nitre, and fix drams of fixed alkali.

With three ounces and a half of ſoſſil ſalt, diſſolved half an ounce of nitre.



With half an ounce of cream of tartar, dissolved half an ounce of Sedlitz salt, and half an ounce of fixed alkali.

With an ounce and a half of vitriolated tartar, dissolved half an ounce of fixed alkali.

With three ounces and a half of Glauber's salt, dissolved two drams of nitre and as much sugar.

With four ounces of soluble tartar, dissolved half an ounce of pure nitre.

With four ounces of Epsom salt, dissolved half an ounce of fine sugar.

With two ounces and a half of sal ammoniac, dissolved five drams of fossil salt.

With an ounce and a half of volatile salt of hartshorn, dissolved an ounce of nitre and half an ounce of sugar.

With four drams and two scruples of borax, dissolved half an ounce of fixed alkali.

With two ounces and a half of alum, dissolved six drams of common salt, and one dram of Epsom salt.

With nine ounces and a half of green vitriol, dissolved an ounce and a half of Sedlitz salt, two drams of nitre, and three ounces of refined sugar.

With nine ounces of blue vitriol, dissolved an ounce of nitre, three drams of common salt, and an ounce of sugar.

With four ounces and a half of white vitriol, dissolved one ounce of refined sugar.

Water has long been considered as an elementary or simple substance. But the chemists of our own time, in their researches into the nature of elastic fluids, have obtained water in circumstances where there is the highest reason to conclude that it is produced by combination; and in other experiments its decomposition into two principles, namely, vital air and inflammable air, is judged to take place.

The powers of nature, which are ever the same, and are continually performing their operations before us, whether we understand them or not, often present facts of the utmost value and importance, which we overlook, or regard with indifference. Hence it happens, that when an enlightened observer makes any discovery, it is almost always observed that somebody has seen the fact before him, or given some confused hints respecting its theory. It is evident however, that the first discoverer, if there be any merit in discovery, is not the man who finds the treasure, and supposes it to be none, but he who is conscious of its value, and applies it to use. On these principles it is, that the claims of the discoverers of the composition of water must be estimated. The facts appear to be as follow:

Previous to the month of October, 1776, the celebrated Macquer, assisted by M. Sigaud de la Fond, made an experiment by burning inflammable air in a bottle, without explosion, and holding a white china saucer over the flame. His intention appears to have been that of ascertaining whether any fuliginous smoke was produced; and he observes that the saucer remained perfectly clean and white, but was moistened with perceptible drops of a clear fluid, resembling water, and which in fact appeared to him and his assistant to be nothing but pure water. He does not say whether any test was applied to ascertain this purity, neither does he make any remark on the fact.

\* Dictionnaire de Chymie, 2d edition, Paris, 1778. Art. Gas Inflammable, vol. II. p. 314, 315.

In the month of September, 1777, Messrs. Buequet and Lavoisier, not being acquainted with the fact, which is incidentally and concisely mentioned by Macquer, made an experiment to discover what is produced by the combustion of inflammable air. They fired five or six pints of inflammable air in an open and wide-mouthed bottle, and instantly poured two ounces of lime-water through the flame, agitating the bottle during the time the combustion lasted. The result of this experiment shewed that fixed air was not produced †.

Before the month of April, 1781, Mr. John Warltire, encouraged by Dr. Priestley, fired a mixture of common and inflammable air in a close copper vessel, and found its weight diminished. Dr. Priestley likewise, before the same period, fired a like mixture of inflammable air and dephlogisticated air in a closed glass vessel, Mr. Warltire being present. The inside of the vessel, though clean and dry before, became dewy, and was lined with a footy substance ‡. These experiments were afterwards repeated by Mr. Cavendish and Dr. Priestley, and it was found that the diminution of weight did not take place, neither was the footy matter perceived ||. These circumstances therefore must have arisen from some imperfection in the apparatus or materials, with which the former experiments were made.

It was in the summer of the year 1781, that Mr. Henry Cavendish was busied in examining what becomes of the air lost by phlogistication, or combustion, and made those valuable experiments which were read before the Royal Society on the 15th of January, 1784 §. He burned 500,000 grain measures of inflammable, with about  $2\frac{1}{2}$  times the quantity of common air, and by causing the burned air to pass through a glass tube eight feet in length, 135 grains of pure water was condensed. He also exploded a mixture of 19,500 grain measures of dephlogisticated or vital, and 37,000 of inflammable air in a close vessel. The condensed liquor was found to contain a small portion of nitrous acid, when the mixture of the air was such that the burned air was not much phlogisticated, that is, when the proportion of vital air was considerable. This great philosopher, who may be considered as the true discoverer of the composition of water, appears to think with Mr. Watt, that in those experiments of Dr. Priestley, wherein the vitriolic and nitrous acids seemed to be converted into vital air, the acids served only to decompose the water, by depriving it of its phlogistic or combustible part; but he thinks it unnecessary to include the consideration of elementary heat, as Mr. Watt does, because in his opinion it is more likely that there is no such thing, and that the bringing the consideration forward in every chemical experiment, in which increase or diminution of heat takes place, might occasion more trouble and perplexity than it is worth ¶.

In the mean time, M. Lavoisier continued his researches, and during the winter of 1781-1782, together with M. Gingembre, he filled a bottle of six pints with inflammable air, which being fired, and two ounces of lime-water poured in, was instantly stopped with a cork, through which a flexible tube communicating with a vessel of dephlogisticated or vital air was passed. The inflammation ceased, except at the orifice of the tube, through which the vital air

† Acad. Par. 1781, p. 470. ‡ Priestley, v. 395. § Phil. Trans. lxxiv. 126. Dr. Priestley supposed the footy matter to be part of the mercury used in filling the vessel. Phil. Trans. lxxiv. 332. § Mr. Lavoisier relates that Dr. Blagden, Sec. R. S. (who was present at the performing of the capital experiment of burning inflammable and dephlogisticated air in a closed vessel on the 24th June, 1781) informed him that Mr. Cavendish had already done the same thing, and obtained water. See the Memoirs of the Royal Academy at Paris for 1781, p. 472; also Phil. Trans. vol. lxxiv. p. 134. ¶ Philosoph. Trans. vol. lxxiv. p. 330.



was pressed, where a beautiful flame appeared. The combustion continued a considerable time, during which the lime-water was agitated in the bottle. Neither this, nor the same experiment repeated with pure water, and with a weak solution of alkali instead of lime-water, afforded the information sought after, for these substances were not at all altered.

The inference of Mr. Warltire respecting the moisture on the inside of the glass in which Dr. Priestley first fired inflammable and common air, was, that these airs by combustion deposited the moisture they contained. Mr. Watt however inferred from these experiments, that water is a compound of the burned airs, which have given out their latent heat by combustion, and communicated his sentiments to Dr. Priestley in a letter dated April 26, 1783\*, and he concludes, that in every case wherein dephlogisticated air was produced, water has been decomposed by the use of some substance, which had a stronger attraction to its phlogiston than is possessed by the dephlogisticated air, which is therefore set at liberty. He repeated some experiments, particularly with a view to decide this point; and in several of them the quantity of dephlogisticated air, added to the acid which came over, greatly exceeded the original weight of acid employed. He dissolved magnesia, calcareous earth and minium respectively, in pale nitrous acid, and, on distilling to dryness, found nearly the whole of the nitrous acid in the retort highly phlogisticated. From common nitre, the dephlogisticated air was sixteen times the weight of the nitrous acid which was missing. Mr. Watt has therefore a claim to the merit of a discoverer with regard to the composition of water, and has the advantage of priority in the discovery of its decomposition.

It does not appear † that the composition of water was known or admitted in France, till the summer of 1783, when M. Lavoisier and M. de la Place, on the 24th of June, repeated the experiment of burning inflammable and vital air in a glass vessel over mercury, in a still greater quantity than had been burned by Mr. Cavendish. The result was nearly five gros of pure water ‡. M. Monge made a similar experiment at Paris, nearly at the same time, or perhaps before.

The theory which has been proposed and explained by M. Lavoisier, wherein such phenomena as chemists have usually accounted for by the disengagement or transition of phlogiston are explained, merely by the engagement or contrary transition of dephlogisticated air, or its base, by him called the oxygenous or acidifying principle, is amply explained in various parts of our work. See COMBUSTION, PHLOGISTON, PRINCIPLES, the METALS and ACIDS. This theory received a great accession from the discovery of the composition of water. For it was easy to attribute the inflammable air which is disengaged in many processes to the decomposition of water, which is undoubtedly present in most of them, instead of supposing it to come from such bodies as former chemists had imagined to contain the principle of inflammability. See ZINC. In the month of September 1783, M. de la Place communicated to M. Lavoisier || his thoughts on the decomposition of water, which from M. Lavoisier's former experiments he concluded to take place in metallic solutions; and these reasons, added to M. Lavoisier's own reflections, induced him to pursue the subject by a new series of experiments.

This assiduous and accurate philosopher was the first who placed a quantity of

\* Phil. Transf. vol. lxxiv. p. 330. † Compare Phil. Transf. vol. lxxiv. p. 138. with the Memoirs of the Royal Academy at Paris for 1781, pages 472 and 474. ‡ The ounce poids de marc being 472. 2 grs. troy, this quantity will be 295 English grains. || Memoirs of the Royal Academy at Paris, 1781, p. 476.

iron filings and pure water in the upper part of a vessel inverted over mercury, and observed that the iron became calcined, inflammable air being at the same time disengaged, the water being, as he says, truly decomposed\*. He then proceeded in conjunction with M. Meusnier to pass the steam of water through a red hot iron tube, and found that the iron was calcined, and inflammable air disengaged; and the steam of water being passed over a variety of other combustible or calcinable substances, produced similar results, the water disappearing and inflammable air being disengaged. These capital experiments are accounted for by M. Lavoisier, and such chemists as do not admit the existence of phlogiston, by supposing the water to be decomposed into its component parts, vital and inflammable air, the former of which is said to unite with the ignited substance, while the latter is disengaged. See IRON, page 406. Consult also the second edition of Kirwan's Phlogiston, with the Notes of the French Academicians.

The experiment of composing water by the combustion of vital and inflammable air has been repeated with success by the French philosophers and others; notwithstanding which, the maintainers of phlogiston are disposed to doubt or deny the composition of water. In certain proportions of the air, and with a rapid combustion, nitrous acid and fixed air are produced. The antiphlogistian philosophers affirm, that the former is produced by the azotic air combining with a portion of the vital air, in which it almost always exists as an impurity. But to this it is objected, that the quantity is too considerable, and is not increased by the actual addition of azotic air to the mixture before combustion. Those who deny the composition of water avail themselves of the very great quantity of this fluid which may be suspended in air. It has been stated to be essential to the aeriform state, and some have gone as far as to conjecture, that the additaments, which together with water form the distinct aerial fluids, may be either not ponderable, or in quantity extremely minute. Various conjectural theories have also been brought forward relative to the primary or most simple component parts of nitrous acid and fixed air, which to me appear to require much more mature reflection and decisive experiment on the part of their authors, before it may be proper to discuss their merits in an elementary work. If the water produced in this capital experiment be supposed to be merely deposited from the aerial ingredients, it will be necessary that this hypothesis should be confirmed by some facts or experiments upon the airs singly, for the purpose of shewing that they really contain water in so large a proportion. But if on the other hand it be affirmed that these fluids do combine and afford water, it appears incumbent on the maintainers of this doctrine to make the experiment, with a strict attention to quantity: that is to say, the weights of the inflammable and vital airs must in the first place be accurately determined; and in the next place, the weight of water which they afford by combustion, together with that of the residue, which eludes that process. A very elaborate apparatus is described at length, with engravings to admeasurement, in the Elements of Chemistry of Lavoisier. Its purpose is to facilitate the combustion of a large quantity of these fluids. The principal artifice consists in a double lever or beam, like that of a balance, at one extremity of which, with a proper contrivance for keeping it in the same vertical line, is suspended a copper cylinder to be used instead of the jar of the pneumatic apparatus, with its mouth immersed in water. At the other end is a

\* Memoirs of the Royal Academy at Paris, 1781, p. 271.



dish or scale, into which weights may be put to regulate the pressure or force by which this cylinder tends either to rise or fall. It would require a treatise of some length, together with engravings, to explain and discuss the methods required to ascertain the temperature and pressure of the included fluid, to facilitate the supply, and, in a word, to make this delicate and important experiment with the requisite precision. I must therefore of necessity refer the reader to the last mentioned treatise, as well as to the 8th and 9th volumes of the *Annales de Chimie*, where the experiments at large of Fourcroy, Vauquelin, and Seguin are inserted. And for the same reason, after giving a short account of their experiments, I shall only make a few remarks relative to the causes and limits of error, which certainly require a more minute and separate investigation than I can pretend to make in this place. The results of the experiments of these chemists, as I find them in Dr. Pearson's Translation of the new Nomenclature, which I have compared with the original in the *Annales de Chimie*, are as under:

To obtain the inflammable air. 1. Zinc was melted and rubbed into a powder in a very hot mortar. 2. This metal was dissolved in concentrated vitriolic acid diluted with seven parts of water. The air procured was made to pass through caustic alkali. To obtain the vital air, two pounds and a half of crystallized marine salt of vegetable alkali, with excess of vital air (see p. 27), were distilled, and the air was transferred through caustic alkali. This experiment was begun on Wednesday May 13, 1790, and was finished on Friday the 22d of the same month. The combustion was kept up 185 hours with little interruption, during which time the machine was not quitted for a moment. The experimenters alternately refreshed themselves when fatigued, by lying for a few hours on matresses in the laboratory.

The volume of inflammable air employed was 25963,563 cubic inches, and the weight was 1039,358 grains.

The volume of vital air was 12570,942, and the weight was 6209,869 grains.

The total weight of both elastic fluids was 7249,227.

The weight of water obtained was 7244 grains, or 12 ounces 4 gros 45 grains.

The weight of water which should have been obtained was 12 ounces 4 gros 49,227 grains.

The deficit was 4,227 grains.

The value of azotic or phlogisticated air before the experiment was 415,256 cubic inches, and at the close of it 467. The excess after the experiment was consequently 51,744 cubic inches. This augmentation is to be attributed, the academicians think, to the small quantity of atmospheric air in the cylinders of the gazometers, at the time the other airs were introduced. These additional 51 cubic inches could not arise from the inflammable air, for experiment shewed that it contained no azotic air. Some addition of this last fluid, the experimenters think, cannot be avoided, on account of the construction of the machine.

The water being examined, was found to be as pure as distilled water. Its specific gravity to distilled water was as 18671: 18670.

Upon these experiments I shall remark, 1. That the elastic fluids were produced very slowly. 2. That the confining medium was water. 3. That the weight of the respective quantities of these fluids could not be ascertained by any process applicable to the whole mass of each, but was deduced by admeasurement, with corrections for temperature, the pressure of the atmosphere, and the arrangement

arrangement of the apparatus. 4. That this admeasurement in cubic inches was reduced into weight by the application of an elementary number, expressing respectively the weight of a cubic inch of each of the fluids. 5. That this elementary number was obtained by an experiment of weighing about 810 cubic inches of each of the fluids in a glass globe, the evacuation and repletion of which was effected by means of the air pump. 6. That the glass vessel when empty weighed 24179 grains, and its contents of inflammable air 354 grains. I suppose that the  $\frac{1}{4}$  grain was the minutest quantity capable of being discerned by the balance thus loaded; and this being about the 10,000th part of the load in one scale, is certainly a considerable degree of accuracy. An error of  $\frac{1}{4}$  of a grain in this part of the process would affect the number expressing the weight of inflammable air in the third figure, without mentioning other causes of inaccuracy. That result may therefore, at best, be considered as estimate in all the figures but the three first. 7. The vital air was near sixteen times as heavy as the inflammable air, and may therefore, as far as relates to this cause of inaccuracy, be admitted nearly to four places of figures. 8. The expansions and contractions of these fluids at different temperatures, were reduced by computation from the experiments of Morveau and Duvernois, which experiments were made upon small quantities only. But on the other hand it must be allowed, that this process was so managed as to require very little correction on these accounts. 9. What may be the limit or magnitude of the errors arising from their admeasurement of cubic inches is not so easy to determine, because it requires not only information respecting the form and magnitude of the measures made use of, but likewise the facility with which the moveable parts of their apparatus adapted themselves to the variations of circumstances. This department does not exhibit much probability of error; but such as it may be, it affects the elementary cubic inch used in the computations of weight.

Yet upon the whole, as the fidelity of these philosophers cannot be suspected, as the product of water so remarkably coincides with the weight of the air which was burned, as there was no vestige of acid produced, and the residue of azotic air was not greater than might be accounted for on the supposition of original impurity; the experiment may be admitted to prove that vital and inflammable air in certain due proportions do unite at the temperature of moderate combustion, and form water. Whether these principles may in any other proportion, or at any different temperature, or by any order of arrangement as to primary and secondary composition, produce any other result, are circumstances which, for any thing we know, are within the limits of possibility, but it does not appear from any facts we possess, that this really happens.

Subsequent to the alledged decomposition of water by means of iron, Messrs. Paets, Van Troostwyk and Deiman gave an account of some experiments by which they produced gradually a quantity of air from water, and instantly caused it to disappear. Their own account is inserted in the Journal de Physique for November 1789. They filled with distilled water a glass tube  $\frac{1}{4}$  of an inch diameter, and 12 inches long, English measure. One extremity of this tube was hermetically sealed; but at the time of sealing, a small gold wire was inserted, and by that means passed through the glass into the tube for the length of one inch and a half. At the distance of  $\frac{1}{4}$  of an inch from the end of this wire, another wire was placed in the tube, which came out at the open end into a small vessel of distilled water in which that end was immersed. For the purpose of passing the electric commotion through these wires, and consequently through the water

between



between them, the sealed end of the tube with its wire was applied to an insulated copper ball at a certain distance from the prime conductor of their electrical machine, at the same time that the extremity of the other wire, which passed through the vessel filled with water, was made to communicate with the external surface of an electrical jar of one foot square, the knob of which touched the prime conductor.

When the electric shock was passed through the water with a very small interval between the copper ball and the conductor, nothing of consequence happened; but when the distance and consequently the shock was increased, so that the extremity of each wire became tipped with light, a great number of very minute bubbles of air were produced at each commotion, which had the appearance of a continual flux between the two extremities. This production of air was more considerable, and the bubbles at the same time larger, when the distance between the copper ball and the prime conductor was increased, so that sometimes a small spark was seen to pass from the upper wire into the water. The air obtained in this manner occupied the upper part of the tube, and gradually increased in quantity by the continuance of the process, until the water became depressed below the extremity of the upper wire. At this instant the electric spark, which passed through a small portion of the air from the upper wire to the water, set fire to the air, precisely in the same manner as happens with a mixture of inflammable and vital air, and the whole disappeared, excepting a very small residue. This residue being taken out, the experiment was again repeated with the same success. The experiment was repeated several times with the same result; excepting only, that the residue of air after each inflammation appeared to be less and less.

Several chemists found it difficult to repeat this experiment, on account of the facility with which the electric shock from wires under water breaks the containing tube. To prevent this effect, these philosophers were careful that the distance between the two wires should be too great for a spark to pass from the one to the other. And Dr. Pearson, before whom the experiment was lately repeated by Mr. Cuthbertson, asserts that the discharges were interrupted; by which word electricians commonly understand, that part of the circuit is an imperfect conductor. It is probably of consequence that the stream of electricity should be kept up almost steadily, when the expansion from the extricated bubbles has once been produced. The plate machine of 32 inches diameter used by these philosophers, was so powerful, as to occasion nearly two full explosions from a square foot of glass in each turn. The smaller shocks here mentioned must therefore have been extremely numerous.

Dr. Priestley has lately published in a separate pamphlet, experiments on the generation of air from water. When steam is made to issue from the end of a glass or copper tube into a recipient containing water, every bubble of steam collapses into a small bubble of permanent air. This is generally much purer than common air, and is not found by the test of a candle to contain any mixture of inflammable air. There are some unaccountable circumstances attending this experiment. The quantity of air is greatly diminished if the steam be passed through mercury, even though the mercury be as hot as the steam itself. The production is also much less, if the steam be condensed in part before it passes into the water, which may be done by cooling the outside of the pipe. The production does not appear to be affected by the previous purging of the water from air, by boiling or otherwise. Dr. Priestley varied the experiment, by using the

the same water repeatedly confined by mercury. He repeated the process till he was thoroughly satisfied, that the air was really produced and not extricated from the water. There is another process, used by Dr. Priestley, in which air is extricated from water, by filling a glass vessel with that fluid, the neck of which vessel was narrow and of the length of a barometer tube. When the bulb or body is full and the tube is empty, mercury is poured in till the water rises to the top of the tube. In this situation, the whole is to be inverted over mercury like a common barometer. The mercury then descends and occupies the lowest place, namely the tube itself, and the water above it is thus defended from the pressure of the atmosphere, more completely than in the vacuum of an air pump. Dr. Priestley finds that the water in one of the vessels in this situation, has given out air for upwards of a twelvemonth. These experiments, though loosely related, and given without any numerical indication as to quantity, are curious, and deserve to be repeated. Whether the quantities of air thus obtained by Dr. Priestley were before in a mere state of mixture with the water, as they do not seem to have been considerable, relative to its bulk or weight; in which case his experiments will point out nothing more than a better method of purging water of its air; or whether they lead to new deductions, respecting the composition of water, must, it should seem, be decided by additional experiments.

**WATERS, MINERAL.** The examination of mineral waters with a view to ascertain their ingredients, and thence their medical qualities and the means of compounding them artificially, is an object of considerable importance to society. It is likewise a subject which deserves to be attended to, because it affords no mean opportunity for the agreeable practice of chemical skill. But this investigation is more especially of importance to the daily purposes of life, and the success of manufactures. It cannot but be an interesting object to ascertain the component parts and qualities of the waters daily consumed by the inhabitants of large towns and vicinities. A very minute portion of unwholesome matter daily taken, may constitute the principal cause of the differences in salubrity, which are observable in different places. And with regard to manufactures, it is well known to the brewer, the paper-maker, the bleacher, and a variety of other artists, of how much consequence it is to them that this fluid should either be pure, or at least not contaminated with such principles as tend to injure the qualities of the articles they make. This analysis has accordingly employed the attention of the first chemists. Bergman has written an express treatise on the subject, which may be found in the first volume of the English translation of his *Essays*. Fourcroy has written largely on this subject, and Chaptal in his *Elements of Chemistry* has given a very concise and perspicuous account of mineral waters, and the methods of examining them. As my own experience has not suggested to me any addition to the methods collected and pointed out by these and other eminent chemists; I have thought it best in this place to give the method of examination from Wiegand's General System.

The topography of the place where these waters rise, is the first thing to be considered. By examining the ooze formed by them, and the earth or stones through which they are strained and filtered, some judgment may be formed of their contents. In filtering through the earth, and meandering on its surface, they take with them particles of various kinds, which their extreme attenuation renders capable of being suspended in the fluid that serves for their vehicle. Hence, we shall sometimes find in these waters, siliceous, calcareous, or argillaceous earth, and at other times, though less frequently, sulphur, magnesian earth,



or, from the decomposition of aerated iron, ochre. Thus Count Razoumowski found, that the tepid spring at Loesch, in the Vallais in Switzerland, contained iron impregnated with fixed air; but that this martial salt being very easily decomposed, by reason of the warmth of the water, remained suspended by means of the intestine motion occasioned by this warmth, and turned the silver that was plunged into it, yellow. Besides the substances above mentioned, mineral waters contain many others actually dissolved in them, in abundance, viz. aerial acid or fixed air, mineral alkali, Glauber's salt, calcareous and magnesian earth, selenite, calcareous and magnesian nitre, vitriol, alum, aerated iron, martial vitriol combined with iron more or less calcined, combinations of iron with the muriatic acid, liver of sulphur, hepatic gas; and finally extractive matter, furnished by the bogs through which they may have been strained, before they emerge into the air in the form of springs. Vitriol of copper is seldom found in mineral waters; it is only in the subterraneous waters which flow over copper ores, that vestiges of it are found. Sedative salt has hitherto been found in the water of the lake of Monterotondo only. Arsenic is still rarer, though the ancient chemists pretended to have found it in many mineral waters. Inflammable gas being generally the product of putrefaction, is seldom found in spring waters; and though it is often met with in still waters that stagnate on the surface, it occurs but very seldom in the spring itself. So likewise, the vegetable alkali, being produced by the decomposition of vegetables, is merely an adventitious ingredient in spring waters. The case is the same with respect to vitriolated tartar and nitre; the last however occurs more frequently than other matters. Volatile alkali being produced chiefly by the decomposition of animal substances, is seldom met with. It is but of late that terra ponderosa, magnesia, and the different combinations of these substances have been found in mineral waters.

Lastly, as the acids always tend to combine with other substances, it is hardly possible to find them here in an uncombined state.

From this synoptical view of the different ingredients contained in mineral waters, it is evident, that these substances occur in two different distinct states, viz. 1. As being suspended in them: and 2. as being dissolved in them in the form of a salt.

The investigation of mineral waters consists: 1. In the examination of them by the senses. 2. In the examination of them by re-agents. 3. In the analysis properly so called.

The examination by the senses consists in observing the effect of the water as to appearance, smell and taste.

The appearance of the water, the instant in which it is pumped out of the well, as well as after it has stood for some time, affords several indications, from which we are enabled to form a judgment concerning its contents. If the water is turbid at the well, the substances are suspended only, and not dissolved; but if the water is clear and transparent at the well, and some time intervenes before it becomes turbid, the contents are dissolved by means of fixed air.

The presence of this gas is likewise indicated by small bubbles that rise from the bottom of the well, and burst in the air while they are making their escape, though the water at the same time perhaps has not an acid taste. This is the case, according to Count Razoumowski, with respect to the tepid spring in Vallais, and the cold vitriolated chalybeate springs at Astracan. But the most evident proof of a spring containing fixed air, is the generation of bubbles on the

water being shaken, and their bursting with more or less noise, while the air is making its escape.

The sediment deposited by the water in the well is likewise to be examined; if it be yellow, it indicates the presence of iron; if black, that of iron combined with sulphur; but chalybeate waters being seldom sulphurated, the latter occurs very rarely. As to the colour of the water itself, there are few instances where this can give any indication of its contents, as there are not many substances that colour it.

The odour of the water serves chiefly to discover the presence of sulphur in it; such waters as contain this substance, smell of liver of sulphur, or rotten eggs.

The taste of a spring, provided it be perfectly ascertained by repeated trials, may afford some useful indications with respect to the contents. It may be made very sensible by tasting water, in which the various salts that are usually found in such waters are dissolved in various proportions. There is no certain dependance however to be placed on this mode of investigation; for in many springs, the taste of Glauber's salt is disguised by that of the sea salt united with it. The water too is not only to be tasted at the spring, but after it has stood for some time. This precaution must be particularly observed, with respect to such waters as are impregnated with fixed air; for the other substances contained in them make no impression on the tongue, till the fixed air has made its escape; and it is for the same reason that these waters must be evaporated in part, and then tasted again.

Though the specific gravity of any water contributes but very little towards determining its contents, still it may not be entirely useless to know the specific weight of the water, the situation of the spring, and the kind of sediment deposited by it.

The examination of the water by means of re-agents shews what they contain, but not how much of each principle. In many instances this is as much as the enquiry demands; and it is always of use to direct the proceedings in the proper analysis.

It is absolutely necessary to make the experiment with water just taken up from the spring, and afterwards with such as has been exposed for some hours to the open air; and sometimes a third essay is to be made with a portion of the water that has been boiled and afterwards filtered. If the water contains but few saline particles, it must be evaporated; as even the most sensible re-agents, such as the solution of silver, and the salts formed by the union of the terra ponderosa with the nitrous and muriatic acids do not in the least affect it, if the salts whose presence is to be discovered by them are diluted with too great a quantity of water. Now, it may happen, that a water shall be impregnated with a considerable number of saline particles of different kinds, though some of them may be present in too small a quantity: for which reason the water must be examined a second time, after having been boiled down to three fourths.

The substances of which the presence is discoverable by re-agents, are:

*A. Alkalis and earths combined with aerial acid.*

Paper stained with brazil wood, will discover the presence of these substances in the water: if the water contains the smallest portion of alkali, they will change its red hue into a colour partaking more or less of the violet. A still greater degree of sensibility is shewn, according to Mr. Watt's experiments, by the tincture of the leaves of the *brassica rubra*, as well as by that of rose leaves.



*(a) Alkaline salts.*

The taste is sometimes sufficient to indicate their presence in mineral waters impregnated with aerial acid; after these waters have been exposed to the air for some time; but for the sake of producing absolute conviction, let a paper stained with turmeric be dipped in the water previously warmed, the colour of this is changed by alkaline salts only, and not by earths; now if the colour of the paper is changed, and a quantity of sal ammoniac put into the water produces a smell of volatile alkali, the water certainly contains fixed alkali.

*(b) Absorbent earths.*

Water which does not change the colour of paper stained with brazil wood or litmus, and which, after having been boiled, does not render lime water turbid, contains absorbent earth: if this earth be of a calcareous nature, it will be precipitated by the acid of sugar, provided the water be taken fresh from the pump; but not after it has been boiled, unless indeed a particle or two of this earth should be dissolved in another acid, but in this case the sediment will not be nearly so considerable as in the other. The case is the same with respect to barytes, or terra ponderosa.

*(c) A mixture of alkaline salts and earth.*

The water having been examined in the above-mentioned method for the purpose of discovering the alkaline salt in it, let part of this water be made warm; if it becomes turbid, there is certainly, exclusively of the alkali, an earth dissolved in it by means of fixed air; besides which, it is possible the alkali may hold another portion of earth suspended.

*B. Neutral salts in general.*

The purest vinous spirit serves to discover their presence; but for the sake of ascertaining that the substance precipitated by it, is a salt perfectly neutralized, the water must be filtered, as soon as the substance has settled, and when the spirit is evaporated, the residuum must be tasted; the taste will be sufficient to direct the experimenter, with respect to the choice of his re-agents.

*(a) Vitriolic salts in general.*

A few drops of the solution of terra ponderosa in the muriatic acid, will be sufficient to discover the smallest particle of any vitriolic salt; the acid of which will fall down combined with the terra ponderosa in the baro-selenite, or barytic vitriol.

*(b) Muriatic salts in general.*

Waters containing these salts, throw down from a solution of silver in nitrous acid, a white precipitate (luna cornea) which is insoluble in nitrous acid.

*(c) A mixture of muriatic and vitriolic salts.*

First, let a solution of the terra ponderosa in nitrous acid be poured into the water till nothing more be precipitated from it; the precipitate being separated, let a solution of silver be poured into the filtered liquor, till it ceases to yield any precipitation. The former of these precipitates indicates the presence of vitriolic, the second, that of muriatic salts; and the difference in the quantity of the sediments shews the different proportion of these substances in water.

*C. Earthy salts.*

Alkali saturated with fixed air, precipitates the earth out of all earthy and metallic salts. But to know whether this precipitate be of a metallic, or merely of an earthy nature, the experiment must be made with the Prussian alkali. If this throws down no precipitate, the former sediment was mere earth.

*(a) Cal.*

*(a) Calcareous salts.*

A few grains of the acid of sugar will discover these salts, provided that the water containing them has been previously boiled; if a precipitate is formed, there is no doubt of their presence.

*(b) A mixture of calcareous earth and calcareous salts.*

In order to ascertain their presence, the water must be boiled; if during the boiling an earth is thrown down, which after having been dissolved in the acetic acid, forms a precipitate with the acid of sugar, and if the water yields at the spring a still greater sediment with the acid of sugar, it contains, besides a calcareous salt, a portion of calcareous earth.

*(c) A mixture of calcareous earth with salts, in which another earth is contained.*

Let a small quantity of a solution of acid of sugar be poured into the water; if it contains calcareous earth, a precipitation will ensue. To the superincumbent water, after it has been decanted off from the earth and filtered, a solution of alkali saturated with fixed air must be added. If another precipitation ensues, there is, besides the calcareous earth, another earthy salt in the water. For the purpose of discovering it, a little diluted acid of vitriol must be poured upon the precipitate, which without causing any effervescence will form Epsom salt, if the precipitate be muriatic earth; regenerated heavy spar, if it be terra ponderosa; and alum, if it consists of earth of alum.

*(d) Muriated or aerated barytes.*

If the water be supposed to contain at the same time terra ponderosa combined with fixed air, and the same earth in a perfectly saline state, means must be used analogous to those that are employed for the discovery of calcareous earth; which is, to boil the water; to dissolve the earth which precipitates in the marine acid; and then try whether the vitriolic acid will produce a precipitate; if it does, the water contains terra ponderosa aerata. After this, let some vitriolic acid be mixed with distilled boiling water; when, if a precipitate is formed, it is owing to the muriatic salt of the terra ponderosa contained in the water.

*(e) Alum.*

The most simple means of discovering whether water of any kind contains alum, are, to boil the water in a very clean copper vessel, when, if it contains alum, it will exhibit a blue colour. When the quantity of alum in the water is small, the blue colour is not sensible; but it may be rendered very manifest by the addition of a little caustic volatile alkali. This method of discovering alum in water by means of copper, is founded on the property of this salt, in virtue of which it always exists with an excess of acid: it is this surplus of acid which acts upon the copper. A more certain method is to pour a solution of fixed alkali into the water, and to see whether the precipitate made by this means dissolves in water impregnated with fixed air; if it does, it is not earth of alum.

*D. Metallic salts.*

Nothing is better adapted to the purpose of discovering the presence of metallic salts in waters, than the Prussian alkali purified by acids. If a solution of this alkali be poured into this water, after it has been exposed for some time to the air filtered, it makes a precipitate, which will be blue, if the water contains iron; brown, if it contains copper; and white, if it contains zinc. In case the Prussian alkali is not at hand, a solution of fixed alkali may be used in its stead. This with iron forms a yellow; with copper, a green; and with zinc, a white.



a white precipitate. This last precipitate becomes yellow, when exposed to the action of the fire.

(a) *Aerated iron.*

Water which contains aerated iron has its colour changed by an infusion of galls, but not by the Prussian alkali; however, after such water has been exposed for some time to the air, the iron is precipitated out of it, and it ceases to be affected by this infusion. If a water exclusively of this aerated iron contains an alkaline salt, the colour struck by the infusion of galls is rather red than violet.

*Iron not much calcined and dissolved in mineral acids.*

Iron calcined to a certain point, will dissolve in vitriolic acid; but if it has been too much, it is not soluble in this, although it be in the muriatic acid. If the iron contained in the water be in this latter state, the water will be made blue by the Prussian alkali, but will not be affected by an infusion of galls. In a water of this kind, let a piece of polished steel be steeped, and the water evaporated till it is reduced to one half. Now, acids having more affinity with iron, while it retains its metallic state, than after it has been deprived of it, the iron in the former state will expel that in the latter, and at the same time partly reduce it; and thereby enable it to strike a black or deep purple colour with an infusion of galls.

(d) *Iron in two different states in the same water.*

A water of this kind deposits ochre, a short time after it is exposed to the air, and yields at the spring, with Prussian blue, a green or olive-coloured precipitate.

*E. Cupreous salts.*

Water which contains these salts, acquires a distinct blue colour from a few drops of volatile alkali, and yields a brown precipitate by the addition of a little phlogisticated alkali.

*F. Salts of zinc.*

Water that contains these salts affords with Prussian blue a white precipitate, which becomes yellow in the fire, and turns white again as soon as it is cold.

*G. Arsenic.*

If this substance be contained in the water, it will be discovered by pouring a solution of volatile liver of sulphur into the water, from which it will be precipitated of a yellow colour. A solution of gold may likewise be used for this purpose. The water may likewise be boiled down, and the residuum be thrown upon live coals; if it smells of garlic the water contains arsenic.

*H. Combination of acids with manganese.*

If, on a little of a solution of vegetable alkali being poured into water, a white precipitate is formed, and if the precipitate becomes black in the fire, and is soluble neither in the nitrous nor vitriolic acid, the water contains manganese.

*I. Liver of sulphur.*

Nitrous acid destroys the odour of the waters which contain these substances, and separates the sulphur. On the other hand, the vitriolic and common marine acids augment the smell, while they separate the sulphur. But if it be requisite to render the sulphur visible, the experiment must be made with a considerable quantity of water, and the whole suffered to stand undisturbed for some time. The solutions of lead, silver, and quicksilver in nitrous acid, and the solution of corrosive sublimate, yield with a water of this kind a brown or else a black

black precipitate; which, when dried, will burn, on a red hot shovel, with a blue flame and a sulphureous smell.

*K. Hepatic air.*

The pure vitriolic and the phlogisticated marine acids neither augment nor diminish the odour of the water that contains this air; they likewise neither render it turbid, nor do they precipitate the sulphur; this last is effected by the dephlogisticated nitrous and marine acids, though in a very small quantity only. At the same time too they deprive the water of its offensive odour. The solutions of quicksilver, lead, and silver, do not yield any precipitate, except there is a considerable quantity of this air employed; and what is more extraordinary, this precipitate does not burn with a flame. The solution of corrosive sublimate, and the nitrous solution of quicksilver made with heat, give with this kind of water a white precipitate. The calx of silver turns black in it, and deprives it of its offensive odour; it loses this smell likewise in a copper vessel, after remaining in it a minute or two.

In order to obtain a water saturated with sulphureous gas, Dr. Hahneman exposes to a white heat, for a few minutes only, a pounded mixture of equal parts of sulphur and unslaked or fresh slaked lime; and throwing half an ounce of this with five drachms of purified tartar into a bottle containing two pounds of pure luke-warm water, stops it quickly with a cork; and after shaking it for ten minutes, and allowing the grosser particles to settle, pours off the milky liquor into another bottle, and mixes it by agitation with three or four tea-cups of thick cream, or half an ounce or two ounces of gum arabic, or half an ounce of gum tragacanth bruised. Calcareous hepar requires 1920 parts of cold, and 840 of warm water: calcareous tartar 800 of cold, and 500 of warm, for their solution.

For a warm bath he takes fourteen ounces of calcareous hepar, and one pound of cream of tartar pounded, and stirs them up in the water of the bathing-tub; or, in 300lb. of water made warm to 100 degrees, he agitates three quarters of a pound of hepar, made with pot-ash, and then stirs up with it very briskly a quarter of a pound of strong oil of vitriol.—Or he takes four parts of scales of iron fused with three of sulphur, till it ceases to yield a blue flame; puts half a pound of this mixed with five pounds of water, into a bottle holding eight or ten pounds; on this he then pours a quarter of a pound of oil of vitriol, instantly stopping it with a bladder tied over and pricked with a needle; sinks it to the bottom of a high bathing-tub, filled with warm water, and mixes the air as it comes out by agitation with the water. Vid. Chem. Annal. ii. Stuck 1788. Also Hahneman, ubem die Arsenickvergiftung. Leipzig, 1786.

*L. Fixed Air.*

Waters which contain fixed air, change the colour of tincture of litmus to red but this colour must be carefully distinguished from the reddish hue exhibited by this tincture when diluted with a great quantity of water, from which it is very different. According to Professor Bergman's method, lime water may likewise be used, a practice which however stands in need of some improvement. When a water contains a certain but small quantity of fixed air, it does not change the colour of the infusion of litmus; and in this case the quantity must be ascertained by distilling the water in a pneumatic apparatus. The taste of the water indicates the presence of this substance, only when



when the water contains a certain quantity of it; for it is by no means to be inferred, when the water does not taste sour, that it contains no fixed air; at the contrary circumstance sometimes takes place. A water of this kind generates bubbles at the spring, which burst at its surface with some noise.

The analysis of mineral waters shews in the first place, how much of each of these substances is contained in the water; and it is performed by evaporating the water, by which means one substance is obtained after another, when each of them is weighed separate. Some mineral waters contain volatile particles, which make their escape during the evaporation of the water; others contain such substances as are liable to be decomposed by evaporation, or may more or less prevent the developement of the other parts.

Lastly, all of them contain fixed substances, that remain behind in a dry and concrete state, after the water is evaporated.

*A. Separation of the volatile substances.*

*(a) In water which contains hepatic air, these substances occur.*

If nitrous acid be poured on a portion of this kind of water, the quantity of sulphur precipitated by it, gives the quantity of the hepatic air contained in the water; each cubic inch of the latter containing a quarter of a grain of sulphur.

*(b) Water separated with fixed air.*

Part of such water is to be evaporated in the method described a little farther on. From another portion of it, according to Professor Bergman, the air is to be expelled, and afterwards mixed with lime water for the purpose of ascertaining the quantity of it. If Bergman's prescription be followed literally, the fixed air will be loaded with vapours of the water, which will pass with it through the mercury, be condensed on its surface, and afterwards absorb part of the air. It is better to pass the air immediately through lime water; for in this case, one part precipitates along with the calcareous earth which it meets with in its passage, as does likewise the remainder if the apparatus be shaken a little. This earth too must be carefully separated by filtration. Now as the quantity of fixed air contained in calcareous earth, and its specific gravity, is very well known, it is very easy to make an accurate estimate of the quantity of fixed air that is contained in the water; for instance, if half a dram of calcareous earth be obtained, the water contains  $18\frac{1}{2}$  grains of fixed air, or  $32\frac{19}{1000}$  cubic inches; allowing with Kirwan, a cubic inch of fixed air to weigh  $\frac{1}{160}$  of a grain. In default of a pneumatic apparatus, provided it be certain that the water does not contain any fixed alkali, it needs only to be mixed with four times its quantity of lime water, and then filtered.

If the water contains alkali, the experiment must be made twice, viz. first at the spring, and afterwards when the water has been boiled; the weight of the second sediment is then to be subtracted from that of the first, viz. of the aerated earth, and it will appear what allowance is to be made for the weight of the fixed air.

*B. Analysis of the volatile alkaline substances.*

If a substance of this kind be suspected in the water, let part of it, after having been weighed, be put in a retort, and about one-third of it drawn off by distillation; a quantity of marine acid is then to be poured on the distilled portion, till the saturation is complete: the sal ammoniac thus obtained is then to be dried and weighed; the quantity of acid in the sal ammoniac being known,

it is easy to estimate that of the volatile alkali in the water. Wenzel's estimate of the volatile alkali contained in sal ammoniac, seems to be more exact than that of Bergman. If these waters contain particles that may be either easily decomposed, or alter the product of the analysis, they must be treated in the following method :

*C. Separation of the substances which are decomposed during the evaporation of the water, and which prevent the separation of the other ingredients.*

These substances are, liver of sulphur and metallic salts. The acid of sulphur which was disengaged during the evaporation, combines with the alkaline substances that may happen to be contained in the water, and changes their nature. In metallic salts the metal becomes calcined, separates from its acid, and enters into new combinations with the other ingredients of the water. Hence the liver of sulphur, as well as the metallic salts, must be decomposed, and an estimate made of the quantity in which they are present in the water previous to undertaking the evaporation.

*(a) Water that contains liver of sulphur.*

For the purpose of analysing a water that contains liver of sulphur, a quantity of nitrous acid must be poured into it sufficient to precipitate all the sulphur. The precipitate is then to be separated and weighed.

*(b) Water that contains metallic salts.*

Pour into this water a solution of Prussian alkali, previously purified by means of nitrous acid; as soon as the precipitation ceases, the water must be filtered, and the precipitate drained and weighed.

*D. Separation of the fixed and unchangeable substances.*

The separation of the volatile bodies, and of such as may prevent the separation of the fixed and unchangeable substances, having been effected; let a certain quantity of the water be weighed, and, after being evaporated to dryness, weighed again. The evaporation is best performed in vessels of glass or china. It is true that a gentle heat only can be used with such vessels, and that consequently the evaporation goes on but slowly in them. But this inconvenience is balanced by the certainty the operator has no other matter united with it.

In whatever manner the evaporation is performed, the residuum consists of salts which are soluble in the purest spirit of wine, of such as are soluble in cold water, and of such substances as cannot be dissolved by either of these menstrua. The first thing therefore to be done, is to pour a quantity of rectified spirit of wine on the residuum, and let them digest together for the space of a few hours in a gentle heat. The liquor is then to be decanted into another vessel, in order that its contents may be further analysed, and in the mean time the analysis of the remainder is to be continued. With this view, a quantity of cold water is to be poured upon the residuum, which must stand in a gentle heat for the space of six or eight hours, and be shaken now and then. The water is then to be decanted off into another glass, and some fresh water added to the remainder; after standing one or two hours longer, the water in both glasses is to be mixed and filtered, and set apart for the purpose of examining its contents. These consist of salts perfectly neutralized, and vitriolic salts, exclusively of selenite. That part of the residuum which is insoluble in water and spirit of wine, consists of different earths, of the selenite, and of the iron that has been dissolved in the fixed air of the water. The bodies which have been dissolved



dissolved in both liquids, are now to be separated from each other, as must the substances that compose the undissolved residuum.

*A. Separation of the substances dissolved in the spirit of wine.*

These may be either sedative salt, common salt, nitrous acid combined with an earth, arsenic, or extractive matter.

There are three methods of separating these substances.

*First method.*

*(a) For sedative salt.*

The vinous spirit is to be mixed with twice its quantity of distilled water, and part of this mixture evaporated; if this be suffered to crystallize, sedative salt is obtained, of all the salts that are soluble in spirit of wine the only one that is crystallizable.

*(b) Salts with a calcareous basis.*

If the re-agents indicate a calcareous salt in the water, the calcareous earth is to be separated by the acid of sugar saturated with alkali. The quantity of the precipitate thus obtained, gives the quantity of the calcareous salt contained in the water. The salt acquired by crystallization, whether it be nitre or digestive salt, shews with what acids the calcareous earth is combined. In order to separate this salt more accurately, the liquor may be evaporated to dryness, and the soluble part of the residuum extracted with spirit of wine; consequently the digestive salt and cubic nitre, being insoluble in the spirit, are left behind. After these are separated, the spirit must be diluted with distilled water, and the undissolved substances separated by the method mentioned below.

*(c) Salts, the basis of which is heavy earth, or barytes.*

If, in consequence of the analysis made with the re-agents, the presence of a salt of this kind is suspected in the water, let a solution of Glauber's salt, or vitriolated tartar, be poured into the water. After this, either the digestive salt, or the nitre, whichever it be, that is formed by this decomposition, must be separated.

*(d) Salts, the basis of which is magnesian earth.*

If the water contains a portion of these salts, there must be added a quantity of fixed alkali to the liquor that is left after the preceding experiment. The consequence of this will be, that the magnesia will be precipitated; and from the crystals, either of digestive salt or nitre, which may be separated either by crystallization or precipitation with spirit of wine, it will appear with what acid the earth was united. If the weight of these last salts, or that of the precipitated earth, be known, the quantity of Epsom salt in the water may be easily estimated.

*(e) Arsenic.*

If there be any reason to suspect this substance in the water, to the above-mentioned liquor, before it is suffered to crystallize, a small quantity of volatile liver of sulphur may be added; the arsenic will speedily unite with the sulphur, and afterwards the digestive salt, or the nitre, whichever of these is present, may be separated from the liquor.

*(f) Extractive matter.*

Last of all, the extractive matter must be separated from the spirit of wine. With this view, the liquor that remains after these various processes must be evaporated to dryness. Some particles of it however adhere to the crystallized salts, as do likewise some saline particles to the extractive matter.

*Second*

*Second method.*  
This method is founded on the observation that, except arsenic, and sedative salt, all others which spirit of wine is capable of holding in solution contain an earth. The vinous spirit charged with those substances, being mixed with a sufficient quantity of water, and the arsenic and sedative salt being thus separated from it, let a solution of silver in nitrous acid be poured into it; the precipitate hereby obtained indicates the quantity of marine acid that was present in the water combined with the earth. The remainder of the liquid is then to be precipitated with fixed alkali: a more precise analysis of the earth obtained, will shew the nature and quantity of the salts of which it made a component part.

If besides these there are in the water other salts, the earth of which is combined with nitrous acid, in this case the quantity of the earth obtained will not correspond with that of the marine acid, as indicated by the solution of silver. But as all salts in which the marine acid is combined with an earth, contain nearly the same quantity of earth, nothing more is necessary to be done, than to subtract from the earth obtained by the foregoing process, the quantity sufficient to saturate the marine acid in a liquid state, and the remainder will give the weight of the earth dissolved in the nitrous acid.

For the purpose of ascertaining the nature and quantity of the earth obtained, let the precipitate made by the fixed alkali be dissolved in nitrous acid, to which must be added, drop by drop, a small quantity of a solution of acid of sugar, saturated with fixed alkali. In consequence of this, the calcareous earth will be precipitated and combined with the acid of sugar, and the weight of the precipitate will point out the quantity of the calcareous earth contained in the liquor. Now, if after this liquor be separated from this precipitate by decantation, and a solution of alkali, saturated with fixed air, be poured into it, the muriatic and aluminous earth will be likewise precipitated. Lastly, let there be poured upon this mixture a quantity of distilled water, saturated with fixed air: the former of these earths will be dissolved, while the latter will be left undissolved.

*Third method.*

The arsenic and sedative salt being separated, let the remaining liquor be diluted with three times its quantity of water, and the earth precipitated from it with fixed alkali; the liquor being decanted off from the earthy precipitate, which must be analysed in the method abovementioned. Let there be poured into the former a small quantity of solution of silver. The weight of the precipitate here produced, shews the quantity of marine acid that was combined with the earth.

*B. Separation of the substances that are soluble in distilled water.*  
These may be fixed alkali saturated with fixed air, all the perfect neutral salts, alum, Epsom salt, and other salts.

*(a) Fixed alkali.*  
It is hardly possible to ascertain the quantity of mineral alkali that is contained in any water by the crystallization of this salt; for some part of it always mixes with the other salts, and it can never be obtained in a pure state. Let therefore any quantity of Epsom salt, but rather more than is sufficient, be taken to saturate the alkali in the water. The water will become turbid, and in the space of five or six hours let fall a quantity of muriatic earth. But the redundant quantity also of the Glauber's salt that may exist in the water, as well as



that of the Epsom salt employed in this process, must be taken into consideration. These are the only means on which any dependance can be placed in analysing alkaline waters.

(b) *Alum and Epsom salt.*

If these salts are found together in the water, either with or without any other salt, the best mode of ascertaining the quantity of them, is to decompose them; thus let a solution of fixed alkali be added drop by drop to the water, till it ceases to render the water turbid. The precipitate being washed, dried and weighed, a quantity of distilled water saturated with fixed air must be poured upon it, which will dissolve the magnesian but not the aluminous earth; the weight of the latter subtracted from the whole of the precipitate will give the weight of both earths. The analysis is to be continued, and the vitriolated tartar formed by the decomposition must be separated. This may be easily done by crystallization.

If the Epsom salt be mixed with Glauber's salt, it is almost impossible to separate them by crystallization, as both of them crystallize at the same time. Here, as before, recourse must be had to the decomposition of them. The portion of Glauber's salt contained in the water may be determined by the weight of the precipitated earth; the same holds good with respect to alum, when mixed with other salts.

(c) *Glauber's salt, common salt, and nitre.*

1. A solution of terra ponderosa in nitrous acid is to be poured into water that has stood some time on the residuum of the evaporated water, and the precipitate dried and weighed. By this means the quantity of Glauber's salt contained in the water will be ascertained.

2. Into this water that has been separated from the abovementioned precipitate by filtration, let a quantity of solution of silver in nitrous acid be poured; this will cause a precipitate, which must be separated from the supernatant liquid, and, when dry, weighed for the purpose of discovering the quantity of common salt contained in the water.

3. If the weight of the Glauber's salt, and common salt, taken together, be still not equal to that part of the residuum that has been dissolved in cold distilled water, this circumstance gives room to suspect that there is nitre in it, the quantity of which is discoverable by the difference of the others.

C. *Separation of the substances contained in that part of the residuum of the water, which is not soluble either in spirit of wine, or in cold water, viz. selenite, iron, siliceous, aluminous, magnesian, calcareous, and ponderous earth.*

I. *Selenite.* The residuum, after being weighed, is to be boiled with five hundred times its weight of distilled water; the selenite will be dissolved, and will pass through the filter with the water, while the iron and the earth will remain behind. The remainder must now be dried upon the filter, and weighed; if the weight be subtracted from its former weight before it was boiled, it will give that of the selenite.

In order to separate the selenite, marine acid may likewise be poured on the residuum; the acid will dissolve the iron and the earths, and the selenite will remain behind, together with a little siliceous matter. For the purpose of ascertaining the quantity of the latter, nothing more is necessary than to wash the residuum with distilled water; what remains after this is siliceous earth, the quantity of which is easily determined.

II. Siliceous earth. The selenite being separated in the former of these methods, upon what remains on the filter after it has been dried and weighed, pour a quantity of marine acid, when it will all dissolve except the siliceous earth, and the deficiency in the weight will determine the quantity of this earth.

III. Iron. Into this solution let there be poured a little Prussian alkali purified by means of marine acid, the iron will be precipitated in the form of Prussian blue.

The Prussian alkali must be previously purified by acids, in order to prevent the precipitation of the earthy salts, and to make the precipitate charge itself more perfectly with the colouring matter. In Professor Bergman's method, the siliceous earth combines with the alkali, and in this case it is very difficult to ascertain the quantity of it.

IV. Calcareous earth. After the separation of the iron by means of the Prussian alkali, the liquor is still charged with different kinds of earths. In order to separate the calcareous earth from this liquor, a solution of acid of sugar saturated with alkali must be added drop by drop, when the calcareous earth will be precipitated in the form of calx saccharata, or calcareous saccharine salt.

V. Magnesian and aluminous earths.

In order to obtain these earths from the liquor standing upon the calcareous saccharine salt, a solution of fixed alkali is to be added to it, till the precipitation ceases; the precipitate, which consists either of earth of alum, or magnesian earth, or both together, is then to be washed, dried, weighed, and put into a large bottle that is perfectly air-tight, and the bottle is to be filled with distilled water perfectly saturated with fixed air; this will dissolve the magnesian earth, and leave the aluminous earth behind.

WATERS, SPIRITUOUS. Spirituous liquors to which a flavour is given by infusion of herbs, distillation from fragrant vegetables, solution of essential oils, sugar, or other ingredients, have been called strong waters. This term was formerly more generally applied than at present.

WAX, is an oily concrete matter gathered by bees from plants.

Wax has been long considered as a resin, from some properties common to it with resins. It has the same consistence as resins have, and like them, it furnishes an oil and an acid by distillation, and is soluble in all oils; but in several respects it differs sensibly from resins. Like these, wax has not a strong aromatic taste and smell, but a very weak smell, and when pure, no taste. With the heat of boiling water no principles are distilled from it; whereas, with that heat, some essential oil, or at least a spiritus rector, is obtained from every resin. Further, wax is insoluble in spirit of wine. If wax be distilled with a heat greater than that of boiling water, it may be decomposed, but not so easily as resins can. By this distillation a small quantity of water is first separated from the wax, and then some very volatile and very penetrating acid, accompanied with a small quantity of a very fluid and very odoriferous oil. As the distillation advances, the acid becomes more and more strong, and the oil more and more thick, till its consistence be such that it becomes solid in the receiver, and is then called butter of wax. When the distillation is finished, nothing remains but a small quantity of coal, which is almost incombustible.

Wax cannot be kindled, unless it be previously heated and reduced into vapours; in which respect it resembles fat oils. The oil of butter of wax may by repeated distillations be attenuated and rendered more and more fluid, because some portion of acid is thereby separated from these substances; which effect is similar



similar to what happens in the distillation of other oils and oily concretes: but this remarkable effect attends the repeated distillation of oil and butter of wax, that they become more and more soluble in spirit of wine; and that they never acquire greater consistence by evaporation of their more fluid parts. Boerhaave kept butter of wax in a glass vessel open, or carelessly closed, during twenty years, without acquiring a more solid consistence. It may be remarked, that wax, its butter, and its oil, differ entirely from essential oils and resins in all the above-mentioned properties, and that in all these they perfectly resemble sweet oils. Hence Macquer concludes, that wax only resembles resins in being an oil rendered concrete by an acid; but that it differs essentially from these in the kind of the oil, which in resins is of the nature of essential oils, while in wax and in other analogous oily concretions (as butter of milk, butter of cocoa, fat of animals, spermaceti, and a wax obtained from a tree in Louisiana) it is of the nature of mild, unctuous oils that are not aromatic, and not volatile, and are obtained from vegetables by expression.

It seems probable, that the acidifying principle, or vital air, and not an actual acid, may be the leading cause of the solidity, or low fusibility of wax. Wax is very useful, especially as a better material than any other, for candles.

Wax may be deprived of its natural yellow disagreeable colour, and be perfectly whitened by exposure to the united action of air and water, by which method the colour of many substances may be destroyed.

The art of bleaching wax consists in increasing its surface; for which purpose it must be melted with a degree of heat not sufficient to alter its quality, in a cauldron so disposed, that the melted wax may flow gradually through a pipe at the bottom of the cauldron into a large tub filled with water, in which is fixed a large wooden cylinder, that turns continually round its axis, and upon which the melted wax falls. As the surface of this cylinder is always moistened with cold water, the wax falling upon it does not adhere to it, but quickly becomes solid and flat, and acquires the form of ribbands. The continual rotation of the cylinder carries off these ribbands as fast as they are formed, and distributes them through the tub. When all the wax that is to be whitened is thus formed, it is put upon large frames covered with linen cloth, which are supported about a foot and a half above the ground, in a situation exposed to the air, the dew, and the sun. The thickness of the several ribbands thus placed upon the frames, ought not to exceed an inch and a half, and they ought to be moved from time to time, that they may all be equally exposed to the action of the air. If the weather be favourable, the colour will be changed in the space of some days. It is then to be remelted and formed into ribbands, and exposed to the action of the air as before. These operations are to be repeated till the wax be rendered perfectly white, and then it is to be melted into cakes, or formed into candles.

The yellow colour of the wax is evidently destroyed by the combined action of the air, of the water, and of the sun. As the volatile sulphureous acid has the property of destroying still more quickly almost all the colours of vegetables, Macquer supposed that this bleaching might be shortened by exposing ribbands of yellow wax to the vapour of sulphur, as is practised for wool and silk.

His annotator observes, that this operation of bleaching wax can be performed well in fine weather only, as it depends chiefly on the action of the sun. This circumstance being attended with much inconvenience to the manufacturers, the discovery of a method of whitening wax, independently of the seasons, would

be very useful, and has been recommended to the attention of chemists by some oeconomic societies. With a view to discover such a method, Mr. Beckman has made experiments, an account of which is published in the 5th volume of the *Novi Commentarii Societatis Regiæ Scientiarum Gottingensis*. According to these experiments, thin pieces of yellow wax were whitened and hardened by being digested and boiled in diluted and undiluted nitrous acid in a few hours. But the wax thus whitened being melted by means of boiling water, was observed to acquire a yellow colour, less intense, however, than it was before it had been treated with the mineral acids. The marine and vitriolic acids were less effectual than the nitrous. He exposed wax to the flames of burning sulphur, but without success. Yellow wax being melted in vinegar was rendered of a gray colour. The oil of tartar whitened wax, but less effectually than acids had done; and this wax being washed in water, and afterwards digested in nitrous acid, was rendered still more white; but upon melting it in water a yellowish tinge returned. He liquefied wax in solutions of nitre and alum, but without any good effect. Spirit of wine, which is recommended by Boyle for this purpose, did indeed whiten the wax, but changed it to a butyraceous substance, so frothy that its bulk was increased thirty times. Reflecting that tartar is purified from its oily particles by means of a calcareous earth, he tried the effects of a kind of fuller's earth, which he threw upon wax liquefied in water, and he agitated the mixture. This method rendered wax of a grayish colour, and is therefore recommended by him as preparatory to bleaching, the time necessary for which, he thinks, may be thus greatly shortened.

Every kind of wax is not equally capable of being whitened, the colour of some adhering so strongly, that it cannot be effaced. Such is the wax that comes from countries in which vines grow. This observation Macquer received from Mr. Trudon, proprietor of the manufactory of wax at Antoni, near Paris.

Wax is employed for many purposes in several arts. It is also used in medicine as a softening, emollient, and relaxing remedy: but it is only used externally, mixed with other substances. It is an ingredient in many pomatums, cerates, ointments, and plaisters, to most of which it gives their due consistence.

The following observations and experiments by Dr. Pearson on a wax-like substance, resembling the *Pé-la* of the Chinese, collected at Madras by Dr. Anderson, and called by him *White Lac*, are extracted from the *Philosophical Transactions* for 1794. I have retained the words of the new Nomenclature as in the original.

Nests of insects resembling small cowry shells were brought to Dr. Anderson, from the woods, by the natives, who eat them with avidity. These supposed nests he shortly afterwards discovered to be the coverings of the females of an undescribed species of coccus; and having noticed, in the Abbé Grosier's Account of China, that the Chinese collect a kind of wax, much esteemed by them, under the name of *Pé-la*, from a coccus deposited for the purpose of breeding on certain shrubs, and managed exactly in the same manner as the Mexicans manage the cochineal insect, he followed the same process with his new insects, and shortly found means to propagate them with great facility on several of the trees and shrubs growing in his neighbourhood.

On examining the substance, he observed in it a very considerable resemblance to



to bees-wax; and noticed, moreover, that the animal which secretes it, provides itself, by some means or other, with a small quantity of honey, resembling that produced by our bees. It is also believed that the white lac possesses medicinal qualities.

It must be remembered, that all the authors who describe the true cochineal insect tell us, that the females when nearly perfect are thickly covered with a white down, or meal, which protects them from the sun and rain, and the attacks of certain insects who are their enemies. It is probable that this substance is of the same nature as the pé-la, and that the secretion of wax in more or less quantity is common to the genus of coccus. It is observable, moreover, that the insect which produces lac, a substance resembling wax, provides itself also with a sweet fluid resembling honey. Hence, a striking analogy between these three animals is observable; and it is far from improbable that future naturalists may discover them to be species of the same genus; and find the means of making the beautiful red colour produced by the lac insect as useful in dyeing as that of the true cochineal.

A piece of white lac, which weighs from about three to fifteen grains, is probably produced by each insect. These pieces are of a gray colour, opaque, rough and roundish, of about the size of a pea, but with a flat side, by which they adhere to the bark. In this flat side there is a fissure which contains a little black matter, the exuviae of the insect.

White lac, in its dry state, has a saltish and bitterish taste, and in the mouth is soft and tough. It appears however from Dr. Anderson's letter, that the taste of this substance recently produced is delicious, so that it is difficult to prevent the children or other persons employed to gather it from eating it.

On pressing a piece of this substance between the fingers, a watry liquid oozes out, which has a slight salt taste; and it is said, that the recently gathered lac is replete with juice.

Although the roundish pieces of this substance yield to pressure between the fingers, they may be broken, and then appear to be perfectly white within, and of an uniform smooth texture. White lac has no smell, unless it be pressed or rubbed till it is soft, and then it emits a peculiar odour.

The lac which had been strained through muslin was of a brown colour throughout its whole substance, was brittle, hard, and had a bitterish taste, without any saltiness, for its watry liquid had been separated by melting.

The pieces of lac gathered from the tree are as light, or lighter than bees-wax; but after being melted and purified by straining, it sinks in water, and therefore is specifically heavier than bees-wax generally is.

White lac melts in water of the temperature of 145° of Fahrenheit's thermometer. In boiling water it readily melted, and the black exuviae were thus separated from the lac.

Two thousand grains of white lac were exposed in such a degree of caloric as was just sufficient to melt them; as they grew soft and fluid, a pretty large quantity of reddish watry fluid, namely 550 grains, which emitted the smell of newly baked bread, oozed out. This liquid was poured off for examination, and the lac was strained through fine cloth repeatedly, till it left no exuviae or other extraneous matter on the filter.

The

The quantity of purified lac thus obtained was 1220 grains. It was yellow like bees wax; hard and brittle as rosin. It had no bitterish, or scarcely any other taste. It melted in alcohol, and also in water, of the temperature of between  $145^{\circ}$  and  $146^{\circ}$ .

Purified white lac adheres very firmly to wood, tin, paper, &c. so that it is an excellent cement on many occasions.

The following experiments were made to discover some of the affinities and combinations of white lac.

1. Yellow purified lac above mentioned was spread thin upon a plate of glass, and exposed to the rays of the sun during the whole of the month of July, 1793, but it was not by this means rendered at all less yellow.

2. A piece of white lac, on boiling in water with powdered charcoal, was absorbed, and disappeared.

3. Purified lac was digested in various proportions of ley of pure pot-ash, in different temperatures, but an uniform or soap-like mass could not be formed. The mixture emitted the smell of palm oil. The lac turned to a brown colour, and had the appearance of a coagulated mass, in the liquid as well as dry state. The liquid filtered from these solutions had a sweetish and bitterish taste. Upon the addition of vinegar, it became very turbid and rose-coloured; and by standing it let fall a copious sediment, which being dried was found to be white lac only rendered more brittle.

4. Ammoniac, or caustic volatile alkali, seemed to combine with the white lac. The compound was a tolerably uniform brown soapy substance. It tasted sweet, and had still a weak smell of ammoniac. It rendered water milky, and this solution became curdy on adding to it acetous acid.

5. Candles of different thicknesses were made of purified white lac above mentioned, with cotton wicks of different thicknesses; and candles were also made of white lac which had been dissolved in sulphuric æther, and in volatile oil of turpentine. They all burned more rapidly, but Dr. Pearson is of opinion that they emitted a less quantity of light, than wax candles of the same size. The candles made of white lac also smoked, and produced a resinous smell.

White lac burned in oxygen gas without affording any smoke, and with a beautifully bright flame.

A small piece of purified white lac, in a platina spoon, was exposed to the apex of the violet blue coloured flame of a candle, by means of the blow-pipe; a small quantity of black matter remained in the spoon, which could not be carried off by a long continued application of the flame; but after keeping the spoon red-hot in the fire for ten minutes, nothing but a very small quantity of gray ash was left.

6. From purified white lac nothing could be extracted by water; nor from the lac in its impure state, except a bitterish mucilage.

7. White lac turned to a black coloured substance by boiling it in concentrated sulphuric acid. The mixture was then diluted with water; and by means of the filter a carbonaceous matter was separated, which on being made red-hot burned in the air without flaming. The filtered liquor, upon evaporation to dryness, afforded no alkaline or other residue.

8. Glass covered with a thin coat of white lac was kept immersed in oxygenated muriatic acid gas, and also in water saturated with this gas, for several months, without producing any apparent change on the colour of the lac, or in its other properties.



9. On about 100 grains of white lac were poured 400 grains of concentrated nitrous acid. In a few minutes time the acid became of a deep orange colour, and on making it hot, nitrous gas was discharged, with an ebullition of the liquid. A fresh discharge of nitrous gas took place on adding more nitrous acid. On applying caloric, to make the acid boil and to melt the lac, this substance was totally dissolved; but on standing to cool, it seemed to be wholly separated from the acid, and was rendered white. On diluting with water the acid from which the lac had separated itself, a very slight curdy precipitation took place; and the same appearance followed on adding ley of pot-ash. On evaporating this acid to dryness, a very small residue of lac was obtained. Dr. Pearson dissolved a little of this substance, by boiling it in concentrated nitrous acid, and poured the solution, while hot, into water; upon which a very copious precipitation instantly took place, of the lac rendered quite white.

10. One hundred grains of the substance under examination were totally dissolved, and very readily, in 500 grains of volatile oil of turpentine. While this solution was hot it was clear, but on cooling it grew opaque and white. On evaporation the whole of the lac was recovered.

11. Fifty grains of white lac readily dissolved in 500 grains measure of sulphuric æther, in the temperature of  $80^{\circ}$ . This solution was not unctuous, or resinous; the lower part of it was like an emulsion, and the upper part of it was transparent and limpid; but both parts contained the substance dissolved. Upon evaporation the lac was recovered in the form of a light white powder, which on melting became a brittle yellow solid, as heavy as before solution.

12. One hundred grains of white lac being digested in 1000 grains measure of alcohol, the specific gravity of which was as 835 to 1000, about half of the substance soon dissolved; and the solution when cold was opaque, white, and thick, as saturated solution of soap in hot spirit of wine appears on cooling. By repeated affusions of alcohol on the residue of these 100 grains, all but about 15 grains was dissolved; and this residue did not appear to be different from lac which had not been digested in this menstruum. This solution afforded, on evaporation, a light white opaque powder, which on being melted was a brittle, yellow, heavy solid, as the substance was before solution.

Saturated solution of white lac in alcohol spread upon paper, cloth, wood, &c. on evaporation left a thin coat of resinous matter, which was not however bright and smooth; and therefore this solution did not afford a good varnish.

Of the experiments which Dr. Pearson made to decompose white lac by fire, he only particularly relates the following one, because among several which he made there was no material difference in the result.

Eight hundred grains of purified white lac were put into a glass retort, to which was affixed an adapter with a large bulb to receive condensed vapours, and the hydro-pneumatic apparatus to collect elastic fluids, or gases. These distilled over 204 grains of yellow strongly empyreumatic oil of the consistence of butter, 400 grains of thin oil which had the smell of tar, near 20 grains of watry liquid containing a little acid, perhaps the pyrotartareous or the sebatic acid; besides 307 cubic inches of gas. In the retort there remained 37 grains of carbonaceous matter, which was a pretty hard cinder, the under surface of which in contact with the glass had seemingly undergone a partial fusion, and the glass itself to which it adhered appeared to have been a little corroded.

The above distilled gas contained no oxygen to the test of nitrous gas; but 32 cubic inches of it were absorbed by milk of lime, and near 86 cubic inches

of

of it were absorbed by yellow oxyd of lead, or massicot, placed in the focus of a lens; during which absorption lead was reduced, and water composed. The remainder of the gas extinguished flame, and was concluded to be nitrogen or azotic gas.

The gas which was obtained by distillation was therefore a mixture of carbonic acid, hydrogen and nitrogén gas. This mixture burned like what has been called heavy inflammable air.

The above 37 grains of carbonaceous matter afforded two grains of muriate of soda, one grain of carbonate of soda, four grains of phosphate of soda. The lixiviated carbonaceous matter being mixed with 300 grains of red oxyd of lead, and exposed to a due degree of fire, yielded about 60 cubic inches of carbonic acid gas, and a little regulus of lead; but there was a residue of carbonaceous matter which could not be burnt away in the fiercest fire in open vessels. This residue was probably carbon, phosphoric acid, and soda, intimately mixed by fusion.

From this analysis, it appears that 100 parts of white lac purified yield,

Butyraceous oil	—	—	25 $\frac{1}{2}$
Thin oil	—	—	50
Water containing acid	—	—	2 $\frac{1}{2}$
Carbonaceous matter, containing phosphoric acid,			
muriatic acid, and soda	—	—	4 $\frac{1}{2}$
Carbonic acid, by estimation	—	—	4
Hydrogen, by estimation	—	—	1 $\frac{1}{2}$
Nitrogen or azote, by estimation	—	—	10
			98
Deficiency by waste and error, by estimation	—	—	2
			100 parts.

When this experiment was made with unpurified white lac, the proportion of water and carbonaceous matter was much greater than in the preceding experiment. On account also of the water, it was extremely difficult to prevent the substance boiling over and bursting the vessels.

Charcoal of wood being mixed with white lac, the oil seemed to distil over more readily, with less water, and was paler coloured oil than in the preceding experiment.

White lac was also distilled from pot-ash, without any material difference in the result, excepting that the oils which distilled over were thicker.

The following experiments were made on the liquid contained in white lac:

(a) On pressing, between the fingers, the pieces of white lac, in the state in which they are taken from the tree or shrub (although they are apparently quite dry and brittle, and have been kept several years), a watery liquid oozes out; by which paper stained with turnsole is instantly turned to a red colour.

(b) The 550 grains of reddish watry liquid above mentioned to have been separated from 2000 grains of white lac, were filtrated through paper in order to separate mucilage.

(aa) This filtrated liquid has a slightly saltish taste, with bitterness, but is not at all sour.

(bb) When made hot, it smells precisely like newly baked hot bread.

(cc) On



(cc) On standing it grows somewhat turbid, and deposits a small quantity of sediment.

(dd) Its specific gravity in the temperature of  $60^{\circ}$  was to distilled water as 1025 to 1000.

(ee) A little of this liquid having been evaporated till it grew very turbid, on standing afforded small needle-like crystals in mucilaginous matter.

(c) About 250 grains of the liquid (b) were poured into a retort which held one ounce measure, to which was joined a receiver containing two shreds of paper, one stained with turnsole, and the other had been dipped in solution of sulphate of iron. As the liquor grew warm, mucilage-like clouds appeared, but when it grew hot they disappeared; and about the temperature of  $200^{\circ}$  it distilled over very fast. On distillation to nearly dryness, a small quantity of extractive matter remained. The distilled liquor while hot smelt like newly baked bread, and was perfectly transparent and yellowish. The paper stained with turnsole was not reddened; nor was that which had been immersed in solution of sulphate of iron turned to a blue colour, upon moistening it with ley of pot-ash.

(d) The flame of a candle being applied by means of a blow-pipe to the extractive matter (c), the whole of it was burnt away, except what produced a black mark upon the spoon; in which no trace of alkali was detected by paper stained with turmeric.

(e) About a hundred grains of the yellowish transparent liquid (c) being evaporated till it grew turbid, after being set by for a night, afforded acicular crystals; which under a lens appeared in a group, not unlike the umbel of parsley. The whole of these crystals could not, probably, have weighed a quarter of a grain. They tasted only bitterish.

(f) One hundred grains of the yellowish transparent liquid (c) being evaporated, in a very low temperature, to dryness, a blackish matter was left behind, which did not entirely disappear on heating the spoon containing it very hot in the naked fire; but on heating oxalic acid to a much less degree, it evaporated, and left not a trace behind.

(g) Carbonate of lime (chalk) readily dissolved, with effervescence, in the liquid (c). The solution tasted bitterish, did not turn paper stained with turnsole to a red colour, and a copious precipitation ensued on adding to it carbonate of potash (mild vegetable alkali). A little of this solution of lime, and also of alkali, being evaporated to dryness, and the residue being made red-hot, nothing remained but carbonate of lime, and carbonate of pot-ash.

(h) The above distilled liquid (c) did not render nitrate of lime turbid; but

(i) It produced turbidness in nitrate and muriate of baryt.

(k) To 500 grains of the reddish coloured liquid obtained by melting white lac, Dr. Pearson added ley of carbonate of soda, till the effervescence ceased, and the mixture neither reddened paper stained with turnsole, nor turned paper stained with turmeric to a brown colour. The quantity of dry carbonate of soda used in the ley was three grains. A quantity of mucilaginous matter, with a little carbonate of lime, was precipitated during this combination. The saturated solution being filtrated and evaporated to a due degree, it afforded, on standing, deliquescent crystals.

(l) A little of the crystallized salt (k) by exposure to fire left only a residue of carbonate of soda.

(m) The reddish liquid obtained by melting the white lac being filtrated, the following precipitants were added; namely,

1. Lime.

1. Lime-water, which produced a light purple, turbid appearance, and on standing, there were just perceivable clouds.

2. Sulphurat of lime (calcareous liver of sulphur) occasioned a white precipitation; but Dr. Pearson could not perceive the smell of sulphurized hydrogen gaz (hepatic air).

3. Alcohol of gall nut (tincture of gall nut) induced a grey precipitation.

5. Sulphate of iron (green vitriol) produced a purplish colour, but no precipitation; nor did any precipitation take place on adding to this mixture, first a little vinegar, and then a little pot ash.

5. Acetite of lead (sugar of lead) occasioned a reddish precipitation, which redissolved on adding a little nitrous acid.

6. Nitrate of mercury (solution of mercury in nitrous acid) produced a whitish turbid liquor.

7. Oxalic acid produced immediately a precipitation of white acicular crystals.

8. Tartrate of pot-ash (soluble tartar) being added, a precipitation took place which much resembled that which takes place on adding tartareous acid to tartrate of pot-ash; but the precipitated matter by the liquid from the white lac did not re-dissolve on adding pot-ash.

With respect to the nature of the liquid contained in white lac, our author judges it to belong to the genus of acids, because it changes turnsole to a red coloured substance, and neutralizes fixed alkali and lime (*g*) (*k*).

This acid liquor is most probably secreted at the same time with the white lac; and therefore the white lac coccus, like the ant, and some other insects, has organs for secreting an acid.

As this acid is destructible by fire (*f*) (*g*) (*l*), and as it affords carbon (*f*), it must be referred to the animal or vegetable acids.

From the precipitation of tartrate of pot-ash (*m*, 8) resembling tartar, this acid might be supposed to be the tartareous; but as this precipitate is not again dissolved on adding pot-ash; as it has no sour taste; as it evaporates in 200° of caloric (*b*); as the combination with lime is readily soluble in water, and decomposed by pot-ash (*g*) (*m*, 1); and as the combination with soda is a deliquescent salt (*k*), this acid cannot be considered to be tartareous. Nor does this liquid appear, from the above experiments, to be any one of the other known vegetable or animal acids. The other properties, shewn by the experiments, except the precipitation of tartrate of pot-ash, and the peculiar smell above mentioned, are either those common to every species of acid, or are possessed by several of them. For although this acid possesses several properties common to all acids, and some properties which belong to a few species only, there is not any one of the already known acids that has the smell, when heated, above mentioned; that precipitates tartrate of pot-ash, but does not serve to compose acidulous tartrate of pot-ash; that, besides, having these properties, is vapour in the temperature of 200° without decomposition, has not a sour but a bitterish taste, and forms a soluble compound with lime, which is decomposable by pot-ash.

The precipitation by oxalic acid, it is probable, was occasioned by a small quantity of lime which the undistilled liquid of white lac contains.

Dr. Pearson observes moreover, that he does not refer to the other phenomena in the experiments, because they are produced by acids in general.

Whether the above liquid from white lac be a new acid, or one of the acids already known, but disguised by mixture or union with other bodies, he leaves to the decision of future experiments, and to the judgment of learned chemists.

Dr.



Dr. Pearson makes the following remarks and conclusions from the preceding observations and experiments :

1. White lac being unctuous when in the fluid state ; having little or no smell and taste, unless heated ; being insoluble in water ; being inflammable in oxygen gas ; and decomposed by fire alone, in close vessels, before evaporation, it seems to belong to the genus of fat, or fixed oils : but it differs from them, and resembles the volatile oils and resins, in being brittle and semi-transparent ; in being soluble in alcohol ; in composing an imperfect soap with fixed alkalis ; in dissolving readily in sulphuric æther.

2. As bees wax and white lac seemed to be alike in many properties, Dr. Pearson extended the comparison by some experiments on bees wax.

Bees wax when first secreted is always white, and it is often white when made into the comb. It remains white after being melted.

White lac becomes yellow, on purification by melting and straining.

Bees wax has a peculiar smell when cold. White lac has a smell only when made hot, and it is a different one from that of bees wax.

Bees wax is less brittle and hard than white lac. The former is generally specifically lighter than the latter ; for bees wax often floated upon cold water, but purified lac fell to the bottom.

Bees wax melts at about  $142^{\circ}$  ; and therefore in a few degrees less caloric than white lac.

Bees wax does not adhere so firmly to different bodies as white lac.

Yellow bees wax can be rendered white by exposure to the solar light, or by oxygenated muriatic acid, but this lac could not be bleached.

Bees wax formed a soap-like mass by union with pot-ash, which was soluble like common soap in water, but this lac afforded an imperfect soap.

It is well known that bees wax burns without affording almost any smoke or smell, and produces a steady light. Dr. Pearson did not find that white lac, united with oil of olive, formed a wax little inferior to bees wax, which is said to be the case with the pé-la of the Chinese. By this union he made white lac whiter and as soft as bees wax ; but it still afforded smoke, a resinous smell, and an unsteady light, as before.

Water extracted nothing from pure bees wax.

Nitrous acid, in the cold, only rendered it white ; but, on boiling, the lac wholly dissolved ; and like the white lac, on cooling, it separated, and was rendered white.

Oil of turpentine, and

Sulphuric æther formed compounds with bees wax similar to those with white lac. The solution of bees wax in sulphuric æther, on evaporation left a white powdery substance, which on melting was found to be common yellow wax.

Alcohol, the specific gravity of which to water was as 835 to 1000, dissolved bees wax with much more difficulty, and in much smaller proportion, than white lac. By digestion in this menstruum, at the temperature of  $130^{\circ}$  to  $140^{\circ}$ , it appeared that bees wax was totally soluble ; but the same wax by repeated digestions became more and more difficultly soluble ; and yet it did not appear that the last portion of wax was different in its other properties from wax which had not been digested.

On evaporation of this solution to dryness, a white substance in a powdery form remained, which being melted was yellow wax.

Bees wax, on decomposition by fire, in close vessels, with the hydro-pneumatic apparatus

apparatus affixed, yielded resembling or nearly similar substances to those obtained on the analysis of white lac by fire ; for 1800 grains of bees wax gave 1200 grains of white butyraceous oil, with a little thin brown oil, and a very small quantity of water and acid ; and a very large quantity of hydrogen and carbonic acid gas, with which was probably mixed nitrogen gas ; but Dr. Pearson was prevented by an accident from determining the presence of this last gas. In the retort there remained only about ten grains of carbonaceous matter. The smell of the empyreumatic oils was very different from those of white lac.

3. White lac appears to have the same kinds of affinity as bees wax ; but many of their combinations are so very different in the two cases as to determine white lac and bees wax to be different species of substances, although they agree with one another in more properties than they do with any other known bodies. As to the pé-la of the Chinese, we cannot judge of it unless a more particular account had been given of its qualities.

4. White lac and bees wax appear to be homogeneous substances, and to consist of the same kind of constituent parts, but the proportion of these parts is very different in the two substances ; and hence the difference in the properties of bees wax and white lac. Dr. Pearson considers the phosphate of lime, the soda and muriate of soda, as extraneous to the composition of lac. The different composition of the two substances may, he thinks, enable us to explain in a probable manner the different action of other bodies upon them. For instance, as it appears that a much greater proportion of carbon enters into the composition of white lac than bees wax, the quantity of oxygen gas in atmospheric air, applied under the usual circumstances of combustion, is not sufficient to combine with the whole of the carbon, and other components of a given part of white lac, wherefore a portion of carbon remains uncombined, in the form of soot, or a sublimate ; but when oxygen gas is applied, the whole of the carbon is combined with it, and of course no smoke appears.

The smaller proportion of carbon in bees wax than white lac, affords a probable reason why there is less smoke during the combustion of bees wax than white lac.

It appears reasonable to conclude, that white lac might be made to serve for illumination and combustion as well as bees wax, either by diminishing the proportion of carbon, or by increasing the proportion of the other components.

**WEIGHTS.** For a table of weights see **BALANCE**. It would certainly be very advantageous for science, if all chemical operations were made with weights decimally divided. For though the absolute quantities used by philosophers in different nations would not by this means be known, yet the proportional results would be every where the same. As the writings of the French chemists frequently convey accounts of weight in pounds, marks, gros, or grains, it may be useful in this place to observe, that

The Paris pound contains 2 marks, and is to the English troy pound as 21 to 16. It is equal to 7560 troy grains.

The Paris mark contains 8 Paris ounces.

The Paris ounce contains 8 Paris drams or gros, and is equal to  $472\frac{1}{2}$  troy grains.

The Paris dram or gros contains 3 Paris scruples, or deniers, and is equal to 72 Paris grains, or to  $59\frac{1}{2}$  troy grains.

The Paris scruple or denier contains 24 Paris grains, and is equal to  $19\frac{1}{4}$  troy grains.

The



The Paris grain is the  $\frac{1}{5175}$ th part of a Paris pound, and is to the troy grain as 7560 to 9216.

WELD, or WOALD (*reseda luteola*, Lin.), is a plant very common in the environs of Paris, in most of the French provinces, and in a great part of the rest of Europe. It pushes out long narrow leaves, of a lively green: from the midst of these leaves the stalk rises to the height of three or four feet, frequently branchy, and furnished with leaves, narrow like the radical ones, but shorter as they approach the flowers, which are disposed in long spikes. The whole of the plant is used for dyeing yellow.

Two sorts of weld are distinguished. The bastard, or wild, which grows naturally in the fields; and the cultivated, the stalks of which are smaller, and not so high. For dyeing, the latter is preferred, it abounding more in colouring matter. The more slender the stalk, the more it is valued.

When the weld is ripe, it is pulled, dried, and made into bundles, in which state it is used.

When the decoction of weld is very strong, it has a yellow colour inclining to brown: if it be greatly diluted with water, its yellow, which is more or less pale, inclines a little to green.

If a little alkali be added to this decoction, its colour grows deeper, and after a certain time, a little ash-coloured precipitate falls down, which is not soluble in alkalis.

Acids in general render its colour paler, and occasion a little precipitate, which will dissolve in alkalis, giving them a yellow colour inclining to brown.

Alum forms with it a yellowish precipitate, and the liquor retains a fine lemon colour. If a solution of alkali be poured into this liquor, a whitish yellow precipitate, soluble in alkalis, is thrown down, but the liquor still remains coloured.

Solution of common salt, or of sal ammoniac, renders the liquor turbid, and its colour at first a little deeper; by degrees a deep yellow precipitate forms, and the supernatant liquor retains a pale yellow colour, a little inclining to green.

Solution of tin produces a copious bright yellow precipitate: the liquor remains a long time turbid, but slightly coloured.

Vitriol of iron produces a plentiful dark gray precipitate, and the supernatant liquor is brownish.

Vitriol of copper occasions a brownish green precipitate, and the liquor preserves a pale green colour.

The yellow communicated to wool by weld has little permanency, if the wool be not previously prepared by some mordant. For this purpose alum and tartar are used, by means of which that plant gives a very pure yellow, which has the advantage of being permanent.

For the boiling, which is conducted in the common way, Hellot directs four ounces of alum to every pound of wool, and only one ounce of tartar: many dyers, however, use half as much tartar as alum. Tartar renders the colour paler, but more lively.

For the welding, that is for the dyeing with weld, the plant is boiled in a fresh bath, inclosing it in a bag of thin linen, and keeping it from rising to the top by means of a heavy wooden cross. Some dyers boil it till it sinks to the bottom of the copper, and then let a cross down upon it: others, when it is boiled, take it out with a rake and throw it away.

Hellot directs five or six pounds of weld for every pound of cloth; but dyers seldom use so much, contenting themselves with three or four pounds, or even much less. Many indeed add to the weld a little quick-lime and ashes, which favour the extraction of the colouring matter, and heighten its colour, but at the same time render it liable to be changed by the action of acids. The quantity of weld, however, ought to be proportionate to the depth of the shade to be obtained.

Lighter and brighter shades may be obtained by dyeing after deeper ones, adding water at each dipping, and keeping the bath boiling: but light shades procured in this way are not so lively as when fresh baths are used, proportioning the quantity of weld to the depth of the shade.

Common salt added to the weld bath renders its colour richer and deeper: vitriol of lime, or gypsum, also deepens it: but alum renders it paler and more lively; and tartar still paler. Vitriol of iron makes it incline to brown. The shades obtained from weld may be modified by such additions, by the proportion of the weld, by the length of the operation, and by the mordants employed in preparing the stuff. Thus Scheffer says, that by boiling the wool two hours with a fourth its weight of solution of tin, and the same of tartar, washing it and boiling it fifteen minutes with an equal weight of weld, it will take a fine yellow, which, however, will not penetrate its internal texture. Mr. Poerner also directs the cloth to be prepared as for dyeing scarlet. By these means greater brightness and permanency are given to the colour, which, *ceteris paribus*, is at the same time lighter.

The colour may be modified also by passing the cloth, when it comes out of the dye, through another bath. Thus, to produce a golden yellow, the cloth, when it comes out of the welding, may be passed through a slight madder bath; and for a tawny (*tannée*), through a bath made with a little foot.

To dye silk plain yellow, in general no other ingredient than weld is used. The silk ought to be scoured in the proportion of twenty pounds of soap to the hundred, and afterwards alumed and refreshed, that is, washed after the aluming.

A bath is prepared with two pounds of weld for each pound of silk, which after a quarter of an hour's boiling is to be passed through a sieve or cloth into a vat; when it is of such a temperature as the hand can bear, the silk is put in, and turned till the colour is become uniform: during this operation the weld is boiled a second time in fresh water; about half of the first bath is taken out, and its place supplied by a fresh decoction. This fresh bath may be used a little hotter than the former; too great a degree of heat however must be avoided, that no part of the colour already fixed may be dissolved; it is to be turned as before, and in the mean time a quantity of cendres gravellées is to be dissolved in a part of the second decoction; the silk is to be taken out of the bath, that more or less of this solution may be put in, according to the shade required. After it has been turned a few times, a hank is wrung with the pin, that it may be seen whether the colour be sufficiently full, and have the proper gold cast: if it should not, a little more of the alkaline solution is added, the effect of which is to give the colour a gold cast, and to render it deeper. In this way the process is to be continued, until the silk has attained the desired shade; the alkaline solution may also be added along with the second decoction of the weld, always taking care that the bath be not too hot.



If we wish to produce yellows with more of a gold or jonquille colour, a quantity of anotta proportioned to the shade required must be added to the bath along with the alkali.

For the light shades of yellow, such as pale lemon or canary-bird colour, the silk ought to be scoured as for blue, because the shades are more beautiful and transparent in proportion as the ground on which they are laid is whiter: the strength of the bath is proportioned to the shade we wish to obtain; and if we intend that the yellow should have a tinge inclining to green, more or less of the indigo vat is added, if the silk has not been azured. To prevent the shades from being too deep, the silk may be more slightly alumed than usual.

Scheffer directs that the silk should be soaked twenty-four hours in a solution of tin, made with four parts of nitrous acid, one of common salt, and one of tin, and saturated with tartar; that it should be washed, and boiled half an hour with an equal quantity of weld flowers. He says, that a fine straw-colour is thus obtained, which possesses the advantage of resisting the action of acids. By following this process, very little tin can remain in the solution, because the acid of tartar precipitates it.

In dyeing cotton yellow, we begin by scouring it in a bath prepared with the ley of the ashes of green wood; it is then washed, dried, and alumed with one fourth of its weight of alum; after twenty-four hours it is taken out of the aluming, and dried without being washed. A weld bath is then prepared, with the proportion of a pound and a quarter of weld for each pound of cotton; in this the cotton is dyed, by being turned and wrought in it until it has acquired a proper shade; it is taken out of this bath to be soaked for an hour and a half, in a solution of vitriol of copper or blue vitriol, in the proportion of one fourth of the weight of the cotton; it is then thrown, without being washed, into a boiling solution of white soap made with the same proportions: after being well stirred, it is boiled in it for nearly an hour, then well washed and dried. Berthollet.

**WHEAT.** The first part of the preparation of farinaceous seeds to be used as food, consists in mechanical trituration; after which, by the addition of water, and the subsequent action of heat, bread and other well known compounds are formed. Wheat is found by experience to be the most nutritive of vegetable matters, and upon chemical examination it proves to possess more of the gluten, or vegeto-animal matter, than any other substance of this class. Messrs. Beccari, an Italian physician, and Kessel Meyer, in Germany, are the first chemists who attempted to separate the different principles of which farina consists. Messrs. Rouelle, Spielman, Malouin, Parmentier, Poulletier de la Salle, and Macquer, have prosecuted these researches much farther than the above-mentioned naturalists. M. Parmentier especially has prosecuted them with very uncommon zeal and industry.

In performing this analysis, a paste is first to be composed of the farina with water; the paste must then be kneaded in an earthen vessel, with water pouring upon it from a cock; the fluid as it falls upon the paste takes up from it a very fine white powder, by means of which it acquires the colour and consistency of milk; let this process be continued till the water runs off clear. The farina is now found to be naturally separated into three distinct substances—a gray elastic matter that sticks to the hand, and on account of its properties has gained the name of the glutinous or vegeto-animal part; a white powder which falls

falls to the bottom of the water, and is the feculum or starch; and a matter which remains dissolved in the water, and seems to be a sort of mucilaginous extract. We shall proceed to an examination of each of these three substances.

The glutinous part is a tenacious, ductile, elastic matter, of a whitish gray colour. It may be extended to twenty times its natural length; and it then seems as if composed of fibres or filaments. When the power by which it was extended ceases to act, it returns with elastic force towards its primary form. By drawing it out in different directions, it may be rendered so thin as to resemble the membranes of animals. In this state it adheres with considerable force to dry bodies, and forms a very tenacious glue, which was used by some artists for the purpose of re-uniting pieces of broken porcelain, long before chemists had discovered the method of obtaining it in large quantities. M. Becari observes, that in the best flour the proportion of the glutinous matter is from a fifth to a third part, or even more:—he remarks too, that this proportion varies according to the season and the nature of the corn.

The glutinous matter has an agreeable and somewhat muscous smell; its taste is insipid; it swells amazingly when exposed to a strength of heat sufficient to dry it quickly. It dries very well by a moderate heat, or even in the dry air. It then becomes semi-transparent and hard, like a strong glue, and like that substance breaks with noise, and with a smooth fracture. If when in this state it be laid on a burning coal, or held over the flame of a taper, it exhibits all the characteristics of an animal matter; it crackles, swells, becomes liquid, is agitated, and burns in the same way as a feather, or a piece of horn, exhaling a strong fetid smell. When distilled in a retort, it affords, like animal matters, water impregnated with volatile alkali, the same alkali in a concrete state, and an empyreumatic oil; the carbonaceous residue is very difficult to incinerate, and is found to contain no fixed alkali.

The gluten, when exposed fresh to a moist and hot air, is altered, and actually putrefies in the same manner as animal matters. If it still retain a little starch, then the starch, passing into the state of acid fermentation, retards and modifies the putrid fermentation of the gluten, and reduces it to a state in which it is much like cheese. In this way Rouelle the younger prepared from this gluten a species of cheese, in taste and smell much the same with Dutch cheese and that of Gruyere.

Water does not at all dissolve this glutinous matter. When boiled in that fluid, it becomes solid, and loses its tenacity and elasticity, but neither acquires a taste nor becomes soluble in the saliva. It may however be observed, that to the water which was used in making the paste the gluten owes its elasticity and solidity. In the farina, this vegeto-animal matter, which is thus susceptible of a solid elastic form, was in an incoherent and pulverulent state; but when the water is poured upon the farina and mixed with it, those particles which are of a glutinous nature absorb the fluid, and are by its means so closely united as to form, in a short time, that sort of elastic solid which is known by the name of gluten. Water therefore contributes greatly to the formation of this substance, which is perhaps to be considered as a peculiar compound saturated with water, and for that reason not capable of absorbing any more. So true is this, that if it be deprived of its water by desiccation, it loses entirely its elastic and adhesive powers.

Most saline substances act either with more or less force on this gluten. The vegetable and mineral alkalis, in a caustic and liquid state, dissolve it with the



help of a boiling heat. The solution is turbid, and on the addition of acids deposits gluten, which however is destitute of elasticity.

The mineral acids dissolve this gluten. The nitrous acid dissolves it with great activity; and M. Berthollet has observed, that this gluten, like animal substances, emits azotic gas, when exposed to the action of the nitrous acid. After the emission of this elastic fluid, the solution affords a great deal of nitrous gas, and takes a yellow colour. By evaporation it affords acid of sugar in crystals. The vitriolic and the muriatic acids form with this substance brown or violet solutions. A sort of oily matter is separated from these solutions; and the gluten exists in them in a real state of decomposition. M. Poulletier, who has made many experiments on this matter, has discovered, that ammoniacal salts may be obtained from these combinations dissolved in water or alcohol, and evaporated in the open air.

Fourcroy remarks, that this substance in many of its distinguishing properties bears a great resemblance to the fibrous part of blood. It is to this gluten the farina of wheat owes its property of forming an adhesive paste with water, and its readiness to rise with leaven. It appears either not to exist, or to exist only in a very small proportion, in the farina of other vegetable substances, such as rye, barley, buck wheat, rice, &c. all of which form solid, opaque pastes, scarcely ductile and brittle, and which can scarce be raised when exposed to the same temperature by which paste of the farina of wheat is raised. No other substance but flour of wheat, therefore, is possessed of all the qualities necessary for making good bread.

Berthollet is of opinion, that this glutinous substance, like animal matters, contains phosphoric salts, which are the occasion of its being so difficult to incinerate. Rouelle the younger has discovered a glutinous substance, resembling that of the farina of wheat, in the green secula of plants, which affords by analysis mild vegetable alkali, and empyreumatic oil, like the vegeto-animal matter of which we have been speaking.

Starch, or the amylaceous seculum, is the most copious part of the farina. This is the substance which is carried off, and afterwards precipitated from the water with which the paste is washed in order to obtain the pure gluten. This substance is very fine, feels soft, and has no perceptible taste. Its colour, when it is extracted by the process above described, is a dirty gray white; but the manufacturers of starch render it exceedingly white, by steeping it in an acid water which they call sour water. It appears from the experiments of M. Poulletier, that the fermentation which takes place in that fluid whitens and purifies the starch, by attenuating and even destroying the extractive mucous substance which is precipitated with it in the first washing. Starch chemically considered is a mucilage of a peculiar nature. This mucilage, which by some chemists has been mistaken for an earth, is very different from the gluten. It does not, like the gluten, diffuse an empyreumatic smell when it burns. When distilled by naked fire, it affords an acid phlegm of a brown colour, and towards the conclusion of the process a very thick empyreumatic oil. The coaly residue is easily enough incinerated, and its ashes are found to contain fixed alkali.

Starch is not soluble in cold water; but when boiled in cold water it forms with the fluid a glue, or rather what we call a paste. This compound when exposed to damp air loses by degrees its consistency, ferments, becomes sour, and is covered over with mouldiness.

The

The nitrous acid affords acid of sugar when distilled from this feculum.

As starch forms the greatest part of flour, there can be no doubt of its being the principal alimentary substance contained both in flour and in bread.

By evaporating the clear water that had been used in washing the paste, and had deposited the starch, M. Poulletier obtained a viscous adhesive matter, of a brown yellow colour, the taste of which was faintly saccharine. This substance, to which he gave the name of mucoso-saccharine, displayed, in combustion and distillation, the same phenomena as sugar. By it, the acid fermentation is produced in the water which swims over starch; for, as Macquer has observed, starch is not at all soluble in cold water. The mucoso-saccharine matter exists in the farina of wheat only in a very small proportion. It may possibly be more copious in the farina of some other vegetable substances.

However small the proportion of this substance in the farina of wheat, yet there can be no doubt of its acting a peculiar part in the fermentation which takes place in paste and causes it to rise. See BREAD.

**WHETSTONE.** A general term among artists and manufacturers for such stones as are used to sharpen tools. I do not know that it is peculiarly appropriated either to Turkey-stone, hone, oil-stone, or the polishing gray argillaceous stone, all which are very different in their qualities from each other.

**WHEY.** The fluid part of milk which remains after the curd has been separated. See MILK. It contains a saccharine matter, some butter, and a small portion of cheese.

**WHITE COPPER.** See TUTENAG.

**WHITE SPANISH, AND WHITE LEAD.** See CERUSE.

**WHITING.** Chalk cleared of its grosser impurities, then ground in a mill, and made up into small loaves, is sold under the name of whiting.

**WILLOW.** The leaves of the willow are mentioned by Scheffer, as proper for giving a fine yellow colour to wool, silk, and thread. Bergman asserts, that the leaves of the sweet willow (*laurier faule*), *salix pentandra*, should be employed, and that the leaves of the common willow give a colour which is for the most part discharged by the sun in a few weeks.

Scheffer directs, that the wool should be left a whole night in a cold solution of three ounces of alum and one ounce of tartar to the pound. The boiling is made with leaves gathered about the end of August or beginning of September, dried in a shady but airy place: as much of these as is thought proper is boiled for half an hour, and half a dram of white pot-ash for each pound is added, to render the colour more bright and deep, and the bath is passed through the sieve; it is kept nearly boiling, and the wool left in it until it has taken the desired colour. He directs the same process for silk, and for thread, except that the proportion of alum is increased an ounce per pound. According to Bergman's account, Mr. Alstroemer has observed, that the colour was rendered richer by soaking the thread with six ounces of alum, wringing and drying it before being dyed; and that half an ounce of pot-ash per pound was required for the complete extraction of the colouring matter.

**WINE\*.** Chemists give the name of wine in general to all liquors that have become spirituous by fermentation. Thus cyder, beer, vinous hydromel, or mead, and other similar liquors, are wines.

\* From Macquer, with alterations.



The principles and theory of the fermentation which produces these liquors are essentially the same. The more general principles we have explained under the article FERMENTATION.

All those nutritive, vegetable, and animal matters, which contain sugar ready formed, are susceptible of the spirituous fermentation. Thus wine may be made of all the juices of plants, the sap of trees, the infusions and decoctions of farinaceous vegetables, the milk of frugivorous animals; and lastly, it may be made of all ripe succulent fruits; but all these substances are not equally proper to be changed into a good and generous wine.

As the production of ardent spirit is the result of the spirituous fermentation, that wine may be considered as essentially the best which contains most of this spirit. But of all substances susceptible of the spirituous fermentation, none is capable of being converted into so good wine, as the juice of the grapes of France, or of other countries that are nearly in the same latitude, or in the same temperature. The grapes of hotter countries, and even those of the southern provinces of France, do indeed furnish wines that have a more agreeable, that is, more of a saccharine taste; but these wines, though they are sufficiently strong, are not so spirituous as those of the provinces near the middle of France: at least, from these latter wines the best vinegar and aqua vitæ are made. As an example, therefore, of spirituous fermentation in general, we shall describe the method of making wine from the juice of the grapes of France.

This juice when newly expressed, and before it has begun to ferment, is called must, and in common language sweet wine. It is turbid, has an agreeable and very saccharine taste. It is very laxative; and when drunk too freely, or by persons disposed to diarrhoeas, it is apt to occasion these disorders. Its consistence is somewhat less fluid than that of water, and it becomes almost of a pitchy thickness when dried.

When the must is pressed from the grapes, and put into a proper vessel and place, with a temperature between fifty-five and sixty degrees, very sensible effects are produced in it, in a shorter or longer time according to the nature of the liquor, and the exposure of the place. It then swells, and is so rarefied, that it frequently overflows the vessel containing it, if this be nearly full. An intestine motion is excited among its parts, accompanied with a small hissing noise and evident ebullition. The bubbles rise to the surface, and at the same time is disengaged a quantity of fixed air of such purity, and so subtle and dangerous, that it is capable of killing instantly men and animals exposed to it in a place where the air is not renewed. The skins, stones, and other grosser matters of the grapes are buoyed up by the particles of disengaged air that adhere to their surface, are variously agitated, and are raised in form of a scum or soft and spongy crust that covers the whole liquor. During the fermentation this crust is frequently raised, and broken by the air disengaged from the liquor which forces its way through it; afterwards the crust subsides, and becomes entire as before.

These effects continue while the fermentation is brisk, and at last gradually cease: then the crust, being no longer supported, falls in pieces to the bottom of the liquor. At this time, if we would have a strong and generous wine, all sensible fermentation must be stopped. This is done by putting the wine into close vessels, and carrying these into a cellar or other cool place.

After this first operation, an interval of repose takes place, as is indicated by the cessation of the sensible effects of the spirituous fermentation; and thus enables

ables us to preserve a liquor no less agreeable in its taste, than useful for its reviving and nutritive qualities when drunk moderately.

If we examine the wine produced by this first fermentation, we shall find that it differs entirely and essentially from the juice of grapes before fermentation. Its sweet and saccharine taste is changed into one that is very different, though still agreeable, and somewhat spirituous and piquant. It has not the laxative quality of must, but affects the head, and occasions, as is well known, drunkenness. Lastly, if it be distilled, it yields, instead of the insipid water obtained from must by distillation with the heat of boiling water, a volatile, spirituous, and inflammable liquor called spirit of wine, or ardent spirit. This spirit is consequently a new being, produced by the kind of fermentation called the vinous or spirituous. See SPIRIT (ARDENT.)

When any liquor undergoes the spirituous fermentation, all its parts seem not to ferment at the same time, otherwise the fermentation would probably be very quickly completed, and the appearances would be much more striking: hence, in a liquor much disposed to fermentation, this motion is more quick and simultaneous than in another liquor less disposed. Experience has shewn, that a wine, the fermentation of which is very slow and tedious, is never good or very spirituous; and therefore, when the weather is too cold, the fermentation is usually accelerated by heating the place in which the wine is made. A proposal which Macquer thinks is a good one, has been made by a person very intelligent in economical affairs, to apply a greater than the usual heat to accelerate the fermentation of the wine, in those years in which grapes have not been sufficiently ripened, and when the juice is not sufficiently disposed to fermentation.

A too hasty and violent fermentation is perhaps also hurtful, from the dissipation and loss of some of the spirit: but of this we are not certain. However, we may distinguish in the ordinary method of making wines of grapes, two periods in the fermentation, the first of which lasts during the appearance of the sensible effects above mentioned, in which the greatest number of fermentable particles do ferment. After this first effort of fermentation, these effects sensibly diminish, and ought to be stopped for reasons hereafter to be mentioned. The fermentative motion of the liquors then ceases. The heterogeneous parts that were suspended in the wines by this motion, and which render it muddy, are separated, and form a sediment called the lees; after which the wine becomes clear: but although the operation be then considered as finished, and the fermentation apparently ceases, it does not really cease; and it ought to be continued in some degree, if we would have good wine. In this new wine a part of the liquor probably remains that has not fermented, and which does afterwards ferment, but so very slowly, that none of the sensible effects produced in the first fermentation are here perceived. The fermentation therefore still continues in the wine, during a longer or shorter time, although in an imperceptible manner; and this is the second period of the spirituous fermentation, which may be called the imperceptible fermentation. We may easily perceive that the effect of this imperceptible fermentation is the gradual increase of the quantity of spirit in wine. It has also another effect no less advantageous, namely, the separation of the acid salt called tartar from the wine. This matter is therefore a second sediment that is formed in the wine, and which adheres to the sides of the containing vessels. As the taste of tartar is harsh and disagreeable, it is evident that the wine, which by means of the insensible fermentation has acquired more spirit, and has disengaged itself



of the greatest part of its tartar, ought to be much better and more agreeable; and for this reason chiefly, old wine is universally preferable to new wine.

But insensible fermentation can only ripen and meliorate the wine, if the sensible fermentation has regularly proceeded, and has been stopped in due time. We know certainly, that if a sufficient time has not been allowed for the first period of the fermentation, the unfermented matter that remains, being in too large a quantity, will then ferment in the bottles, or close vessels in which the wine is put, and will occasion effects so much more sensible, as the first fermentation shall have been sooner interrupted: hence these wines are always turbid, emit bubbles, and sometimes break the bottles, from the large quantity of air disengaged during the fermentation. We have an instance of these effects in the wine of Champagne, and in others of the same kind. The sensible fermentation of these wines is interrupted, or rather suppressed, that they may have this sparkling quality. It is well known that these wines make the corks fly out of the bottles, that they sparkle and froth when they are poured into glasses, and lastly, that they have a taste much more lively and more piquant than wines that do not sparkle; but this sparkling quality, and all the effects depending on it, are only caused by a considerable quantity of air which is disengaged during the confined fermentation which the wine has undergone in close vessels. This air not having an opportunity of escaping, and of being dissipated as fast as it is disengaged, and being interposed betwixt all the parts of the wine, combines in some measure with them, and adheres in the same manner as it does to certain mineral waters, in which it produces nearly the same effects. When this air is entirely disengaged from these wines, they no longer sparkle, they lose their piquancy of taste, become mild, and even almost insipid.

Such are the qualities that wine acquires in time, when its first fermentation has not continued sufficiently long. These qualities are given purposely to certain kinds of wine, to indulge taste or caprice; but such wines are supposed to be unfit for daily use. Wines for daily use ought to have undergone so completely the sensible fermentation, that the succeeding fermentation should be insensible, or at least exceedingly little perceived. Wine, in which the first fermentation has been too far advanced, is liable to worse inconveniences than that in which the first fermentation has been too quickly suppressed; for every fermentable liquor is from its nature in a continual intestine motion, more or less strong according to circumstances, from the first instant of the spirituous fermentation till it is completely putrefied: hence from the time of the completion of the spirituous fermentation, or even before, the wine begins to undergo the acid or acetous fermentation. This acid fermentation is very slow and insensible when the wine is included in very close vessels, and in a cool place; but it does gradually advance, so that in a certain time the wine, instead of being meliorated, becomes at last sour. This evil cannot be remedied; because the fermentation may advance, but cannot be reverted. Wine-merchants, therefore, when their wines become sour, can only conceal or absorb this acidity by certain substances, as by alkalis and absorbent earths. But these substances give to wine a dark greenish colour, and a taste which, though not acid, is somewhat disagreeable. Besides, calcareous earths accelerate considerably the total destruction and putrefaction of the wine. Calces of lead, having the property of forming with the acid of vinegar a salt of an agreeable saccharine taste, which does not alter the colour of the wine; and which besides has the advantage of stopping fermentation and putrefaction, might be

be very well employed to remedy the acidity of wine, if lead and all its preparations were not pernicious to health, as they occasion most terrible colics, and even death when taken internally. We cannot believe that any wine-merchant, knowing the evil consequences of lead, should, for the sake of gain, employ it for the purpose mentioned; but if there be any such persons, they must be considered as the poisoners and murderers of the public.

If wine contains litharge, or any other calx of lead, it may be discovered by evaporating some pints of it to dryness, and melting the residuum in a crucible, at the bottom of which a small regulus of lead may be found after the fusion: but an easier and more expeditious proof is by pouring into the wine some liquid liver of sulphur. If the precipitate occasioned by this addition of the liver be white, or only coloured by the wine, we may know that no lead is contained: but if the precipitate be dark coloured, brown or blackish, we may be certain that lead is contained.

The only substances that cannot absorb or destroy, but cover and render supportable the sharpness of wine, without any inconvenience, are sugar, honey, and other saccharine alimentary matters; but they can succeed only when the wine is very little acid, and when an exceeding small quantity only of these substances is sufficient to produce the desired effect; otherwise the wine would have a sweetish, tart, and not agreeable taste.

From what is here said concerning the acescency of wine, we may conclude, that when this accident happens, it cannot by any good method be remedied, and that nothing remains to be done with sour wine but to sell it to vinegar makers, as all honest wine-merchants do. It may be observed, that the first sensible fermentation having been too far advanced, is not the only cause of the acidity of the wine, but that heat also is capable of producing the same effect. Thus wine which might have been long preserved in a cool place, very quickly becomes sour when placed in a bad cellar; and even as the best cellars have during the winter a degree of heat much superior to that of the atmosphere, it would be very proper, when wine disposed to become sour is to be preserved, to bring it from the cellar in the beginning of winter, and leave it exposed to the air during all that season.

Wine is also liable to various other changes; such as to become ropy and mucilaginous, by the continuance of the fermentative motion: but these details would require an express treatise.

Wine, and the matters produced from wine, as brandy, spirit of wine, vinegar, lees of wine, tartar, are greatly and extensively useful. The lees of wine are employed in the manufacture of hats. These lees, and also tartar by incineration, yield a larger quantity than any other vegetable matter of pure fixed alkali.

Wine has been preferred in all times and in all countries to every other alimentary liquor. We may say in general, that it is good and salutary when taken in small quantities, and that it is pernicious when drunk habitually and in too large quantities. Wine becomes then a true slow poison, which is so much more dangerous, as it is more agreeable. But if we observe more particularly the effects of wine, we shall perceive very great differences depending on different constitutions. Some persons drink habitually large quantities of pure wine, without any sensible inconvenience or disease, or shortening their lives: but, on the contrary, many others do also entirely destroy their health and shorten their lives by an habitual use of wine even in small quantity, and mixed with water. Al-



though it is always more safe and prudent for every person to drink little of it habitually, and this moderation is more indispensably necessary to those whose constitutions wine does not suit.

As the diseases consequent upon the too free use of wine come gradually and insensibly, sometimes even during many years, several persons, especially men otherwise very sober and attentive to health, are every day deceived upon this article, drinking more wine than is suitable to their constitution, and gradually ruining their health without knowing the cause. It is therefore a matter of importance to shew the signs by which wine may be known to be hurtful. We may know that wine does not suit a person, when, after drinking moderately of it, his breath acquires a vinous smell; when it occasions sour belchings and slight pains in the head; and when, after drinking it more copiously than usual, it produces stupefaction, nausea, and drunkenness, especially when this drunkenness is of the morose, peevish, quarrelsome, and irascible kind. Unhappy is that person who suffers these effects from wine, and notwithstanding persists in the habitual use of it. These imprudent persons never fail of coming to a miserable death, preceded by languor; and premature, their common age being about fifty years, or a little more. The diseases to which they are most subject are obstructions in the liver, in the mesenteric glands, and in other abdominal viscera, which are almost always succeeded by an incurable dropsey. Those who digest wine well, do not suffer, or much less sensibly, the above-mentioned effects of drinking it. Their drunkenness is accompanied with vivacity and joy. Such persons seldom die of the obstructions and dropsey above mentioned: but wine is nevertheless so much more dangerous to them, that, as they suffer none of the disagreeable effects, they are more liable to contract the habit of drinking too much. Drinkers of this class generally live somewhat longer than the former; but their constitution generally changes before sixty years of age; and the inheritance of their old age is either a severe gout or palsy, stupidity, imbecility, or an accumulation of these diseases.

We need not mention that the too frequent use of brandy, ratafia, and other spirituous liquors, is still more pernicious and fatal than that of wine.

Wine is used in medicine as a vehicle in the composition of many internal and external remedies. As wine is composed of an ardent spirit, water, extractive saponaceous matter, and acid of tartar, it may be very usefully employed for the extraction of almost all the proximate principles, and consequently of the medicinal parts, of vegetables. Many extracts are made with wine, which may be considered as being more complete than those made with water: but physicians who prescribe these extracts ought to remember, that besides the principles of the vegetables, they also contain the extractive part of the wine, that is, all the principles of wine, excepting the ardent spirit, which is too volatile to remain in an extract.

As wine when good may be preserved during a long time, several medicinal wines prescribed in dispensatories are kept in the shops of apothecaries. Such are the astringent, antiscorbutic, febrifugal wines of the Peruvian bark, of wormwood, chalybeate wine, and others. In many cases, as in several chronical diseases, where tonic, cordial, fortifying and exciting remedies are indicated, physicians prefer the use of wine to water, as a vehicle for the infusion of purgative, aperitive, and other medicinal substances. See SPIRIT, ARDENT.

WOAD, *Isatis*, *Glastrum*, is a plant with long green leaves, the lower ones narrow at both ends; those which grow upon the stalk broad at bottom, like

the head of an arrow. On the tops come forth numerous yellow flowers, which are followed by little flat pods containing the seeds. It grows wild in some parts of France, and on the coasts of the Baltic sea: the wild woad, and that which is cultivated for the use of the dyers, appear to be the same species of plant.

The preparation of woad for dyeing, as practised in France, is minutely described by Astruc, in his Memoirs for a Natural History of Languedoc.—The plant puts forth at first five or six upright leaves about a foot long and six inches broad; when these hang downwards, and turn yellow, they are fit for gathering: five crops are gathered in one year. The leaves are carried directly to a mill, much resembling the oil or tan-mills, and ground into a smooth paste. If this process was deferred for some time, they would putrefy, and send forth an insupportable stench. The paste is laid in heaps pressed close and smooth, and the blackish crust, which forms on the outside, re-united if it happens to crack: if this was neglected, little worms would be produced in the cracks, and the woad would lose of its strength. After lying for fifteen days, the heaps are opened, the crust rubbed and mixed with the inside, and the matter formed into oval balls, which are pressed close and solid in wooden moulds. These are dried upon hurdles: in the sun they turn black on the outside, in a close place yellowish, especially if the weather is rainy. The dealers in this commodity prefer the first, though it is said the workmen find no considerable difference between the two. The good balls are distinguished by their being weighty, of a pretty agreeable smell, and, when rubbed, of a violet colour within.—For the use of the dyer these balls require a farther preparation; they are beaten with wooden mallets, on a brick or stone floor, into a gross powder, which is heaped up in the middle of the room to the height of four feet, a space being left for passing round the sides. The powder moistened with water ferments, grows hot, and throws out a thick fetid fume. It is shovelled backwards and forwards, and moistened every day for twelve days; after which it is stirred less frequently, without watering, and at length made into a heap for the dyer.

The powder thus prepared gives only brownish tinctures of different shades to water, to rectified spirit of wine, to volatile alkaline spirits, and to fixed alkaline lixivia; rubbed on paper, it communicates a green stain. On diluting the powder with boiling water, and after standing for some hours in a close vessel, adding about one twentieth its weight of lime newly flaked, digesting in a gentle warmth, and stirring the whole together every three or four hours, a new fermentation begins, a blue froth arises to the surface, and the liquor, though it appears itself of a reddish colour, dyes woollen of a green, which like the green from indigo changes in the air to a blue. This is one of the nicest processes in the art of dyeing, and does not well succeed in the way of a small experiment.

Astruc proposes the manufacturing of fresh woad-leaves in Europe, after the same manner as the indigo plant is manufactured in America, and thus preparing from it a blue fecula similar to indigo, which from his own experiments he has found to be practicable. Such a management would doubtless be accompanied with some advantages, though possibly woad so prepared might lose those qualities, which now render it in a large business preferable on some accounts to indigo, as occasioning greater dispatch when once the vat is ready, and giving out its colour less hastily, so as to be better fitted for dyeing very light shades.



Hellot suspects that a like blue fecula is procurable from many other vegetables. Blue and yellow blended together compose a green: he supposes the natural greens of vegetables to be compounded in like manner of those two colours; and that the blue is oftentimes the most permanent, so as to remain entire after the putrefaction or destruction of the yellow. The theory is specious, and perhaps just; we know of no other that accounts in any degree for the production of the indigo and woad blue. In the experiments however which Dr. Lewis made, of putrefying different herbs in water, the blue and the yellow colour, if the green was really composed of these, were both destroyed together, no appearance being observed either of one or the other during the whole process.

**WOLFRAM.** Tungsten and Wolfram have already been treated of in the article **ACID OF TUNGSTEN**; and the combinations of metals with the regulus of wolfram have been occasionally mentioned under their respective titles. Little else remains therefore to be said of this metallic substance, than to specify its general characters.

The yellow matter, or calx of wolfram, turns blue by exposure to light, and more intensely if to the light of the sun. By a strong heat in a covered crucible, it becomes of a blueish black colour, with loss of weight, which it recovers, together with its original yellow colour, by calcination, with access of air. These changes to the blue colour appear therefore to be partial reductions\*. One hundred grains of the yellow calx, or acid, being put into a crucible with charcoal powder, well covered, and exposed to a strong heat, became converted into a button of a dark brown colour, and friable with a diminution of forty grains of the original weight. Its specific gravity was 17.6; and upon examination with a glass, a congeries of metallic globules was seen, some of them of the size of a pin's head, which when broke exhibited a fracture resembling steel. Part of this mass being calcined became yellow as at first, and gained twenty-four per cent. in weight. It was not soluble in vitriolic or marine acid; but the nitrous acid, and aqua regia, converted it again into the yellow calx. The yellow calx itself could not be vitrified. Acetous acid converted the yellow colour to a blue.

When equal parts of sulphur and the yellow calx were urged by a strong heat, a blue friable mass remained, weighing less than one-fourth of the whole.

**WOOD.** See **VEGETABLES**.

**WOOD-LICE.** See **MILLIPEDES**.

**WOOD-SORREL.** See **ACID OF SORREL**.

**WOOL** †. The principal differences in wool consist in the length and fineness of its filaments. That which has the finest filaments is reserved for fine cloths. The most beautiful wool is brought to us from Spain. It is said that the highland wool of Scotland is equal in quality to this. Mr. D'Aubenton has shewn that it may be produced in France of a quality not inferior to that of Spain, by folding the sheep through the whole year, and choosing the rams with care. Simple inspection may easily lead to error respecting the fineness of wool, which it is important the manufacturer should know with accuracy; he has proposed a method of attaining that accuracy, by employing a micrometer for com-

\* De Luyarts on Wolfram, p. 58. Gmelin has also made a variety of experiments on this metallic substance. See Crell's Journal, English, iii. The papers are too long to be inserted here, and the facts too insulated to admit of abridgment. † Berthollet on Dyeing, i. 123.

paring, by means of a microscope, the fineness of the wool to be examined with that of other wools chosen as standards\*.

Though the long wool is not so fine as the Spanish, and cannot be employed for fine cloths, it is still very useful for a variety of fabrics; and as the sheep which produce it have much larger fleeces, the profit they bring is not inferior to that of the fine woolled sheep; besides, the cloths made of their wool, being cheaper, have a much more extensive sale. The prosperous state of the woollen manufactures of England is partly owing to our abundance of this wool. But the breed of sheep which produces one or the other kind of wool, is connected with the nature of their pasture, which ought to determine us in the choice of them.

Wool is naturally covered with a kind of grease, which preserves it from moths. Reaumur † has observed, that a stuff may be preserved from these insects, by rubbing it with greasy wool. Hence wool is not scoured till it is about to be dried or spun.

In order to scour wool, it is put for about a quarter of an hour into a kettle, containing a sufficient quantity of water, mixed with a fourth of putrid urine, heated to such a degree as the hand can just bear, and it is stirred from time to time with sticks; it is then taken out and put to drain: it is next carried in a large basket to a stream of running water, where it is moved about till the grease is entirely separated, and no longer renders the water turbid; it is then taken out and left to drain. It sometimes loses in this operation more than a fifth of its weight. The scouring should be carefully performed, because the wool is thereby better fitted to receive the dye.

The ammoniac or volatile alkali, formed in putrid urine, unites with the grease, producing a kind of soap which is soluble in water.

The wool is dyed in the fleece, or before it is spun, chiefly when it is intended to form cloths of mixed colours; or else it is dyed after being spun, and it is then intended principally for tapestry; but it is most commonly dyed after having been wrought into cloth.

When wool is dyed in the fleece, its filaments being separate absorb a larger quantity of the colouring particles than when it is spun; for the same reason woollen yarn takes up more than cloth; but cloths themselves vary considerably in this respect, according to their degree of fineness, or the closeness of their texture: besides, the variety in their dimensions, the different qualities of the ingredients employed in dyeing, and a difference of circumstances in the process, prevent us from relying upon the precise quantities we find recommended for the processes described. This consideration ought to extend to all dyes.

For most colours, wool requires to be prepared by a bath, in which it is boiled with saline substances, principally with alum and tartar: but there are some dyes for which the wool does not require such a preparation; then it must be well washed in warm water, and wrung out or left to drain. This is a general rule which should be observed with respect to all the substances intended to be dyed, in order that the colour may penetrate them more easily, and be distributed more uniformly.

Mr. Monge has explained the operation of felting (*feutrage*) and the effects of fulling, by the external conformation of the wool and hair of animals. He has

\* Mem. de l'Acad. 1779. - Instructions to shepherds and proprietors of flocks.

† Mem. de l'Acad. 1728.



made some curious observations \* on this subject, of which the following are the chief:

Nothing particular can be discovered by means of the microscope in the filaments of wool or in the hairs of animals; yet the surfaces of these bodies are not smooth: they must be formed either of small laminæ placed over each other in a slanting direction from the root towards the point, like the scales of fish, which cover each other from the head of the animal to the tail, or more probably, perhaps, of zones placed one upon another as we see in the horns of animals.

If a hair be laid hold of by the root in one hand, and drawn between the fingers of the other, from the root towards the point, scarce any friction or resistance is perceived, and no noise is heard; but if, grasping it by the point, it is passed in the same manner between the fingers of the other hand, from the point towards the root, a resistance is felt, which did not take place in the former place, and a tremulous motion is perceptible to the touch, and a noise sensible to the ear.

We perceive then, that the texture of the surface of hair is not the same from the root towards the point, as it is from the point towards the root, and that a hair when pressed must meet with greater resistance in sliding or moving towards the point than towards the root; but as it is this texture itself which forms the principal subject of Mr. Monge's memoir, it is necessary to confirm it by some further observations.

If, after having laid hold of a hair between the thumb and fore-finger, we rub them against each other in the longitudinal direction of the hair, it acquires a progressive motion in that direction towards the root. This effect depends neither on the nature of the skin of the finger, nor on its texture; for if the hair be turned, so that the point shall be placed where the root was before, its motion will now be in an opposite direction, that is, it will still be towards the root.

These observations, to which Mr. Monge adds some others, are related of human hair, taken as an example; but they are equally applicable to the filaments of wool, to horse-hair, and to that of animals in general. The surface of all these bodies then is formed of rigid laminæ, laid upon each other like tiles, from the root to the point, which allow a progressive motion towards the root, but oppose one towards the point.

This structure is the principal cause of the disposition to felting (*feûtrage*) which the hair of animals generally possesses; the hatter, by striking the flocculi of wool with the string of his bow (*archet*), detaches and disperses in the air each of the filaments separately; these fall back one upon another in all directions on the table, where they form a layer of a certain thickness; the workman then covers them with a cloth (I suppose linen), upon which he presses on all parts with his hands extended.

The pressure brings the filaments of wool nearer to each other, and multiplies the points of contact; the agitation gives each of them a progressive motion towards its root, by means of which they entangle each other; and the laminæ of each filament taking hold of those of the other filaments which are in an opposite direction, the whole is retained in the state of close contexture, which it had acquired by the pressure.

In proportion as the texture becomes closer, the pressure of the hands ought

\* Observations sur la Mécanisme du Feûtrage. Ann. de Chym. tom. vi.

to be increased, both in order to make it still more compact, and to keep up the progressive motion and intermixture of the filaments, which now meet with greater resistance: but during the whole of this operation, the filaments of wool lay hold of each other only, and not of the cloth, the fibres of which, as has been already observed, are smooth, and have not the same properties in this respect.

The aptitude for felting in wool and hair does not depend entirely on the structure of their surface; it is not enough that each filament should have a progressive motion towards its root; nor that the inclined laminae, by laying hold of each other, should retain the contexture in the state to which it has been reduced by compression: it is also necessary that the filaments should not be straight like needles; for, by a continuance of the motion and pressure, each of them would continue its course progressively, without changing its direction, and the effect of the operation would be to remove them all from the centre, without producing any contexture. It is therefore necessary that each filament should be crooked, so that the extremity nearest the root should be disposed to change its direction continually, to entwine itself round fresh filaments, and to return back upon itself, if it should be so determined by any change in the position of the rest of its length.

Wool possessing this structure naturally, is peculiarly fitted for this kind of work, and may be employed in it, without being subjected to any previous preparation; but the furs of rabbits, hares, and beaver are naturally straight, and cannot be employed alone for felting, without having undergone a previous operation, which consists in rubbing them, before they are stripped, with a brush moistened with a solution of mercury in nitrous acid; this liquor, by acting only on one side of the hairs, changes their rectilinear direction, and communicates to them that disposition for felting which wool naturally possesses.

The operation of fulling woollen stuffs depends on the same property as felting.

The asperity of the surface of the filaments of wool, and their disposition to acquire a progressive motion towards the root, form an obstacle to the spinning of wool, and the working it into stuffs. All the filaments must therefore be covered with a coat of oil, which by filling the cavities renders the asperities less sensible, just as a coat of oil renders a fine file still smoother. When the piece of stuff is wrought, it must be freed from that oil, which gives it a disagreeable smell, renders it dirty, and would prevent it from taking the colour we wish to dye it: for this purpose, it is taken to the fulling-mill, where it is beaten with large beetles, in a trough of water, through which some clay has been diffused. The clay uniting with the oil, renders it soluble in the water, and both are carried off together, by fresh water brought thither by the machine; and after some time, the stuff is found clean scoured. See EARTH, FULLER'S.

But scouring is not the only object in fulling; the alternate pressure of the beetles on the stuff, particularly when the scouring is advanced, produces an effect analogous to that of the pressure of the hatter's hands; the filaments of wool, which compose a thread of the warp or of the woof, acquire a progressive motion, insinuate themselves into the adjoining threads, then into those which are next, and presently all the threads, both of the warp and woof, are felted together. The stuff is now found contracted in length and breadth, and participates both of the nature of cloth and of felt; it may be cut without being subject to ravel, and there is no necessity for hemming the different pieces of it employed to make a garment. If it be common woollen stocking web, the stitches are now no longer subject to run, when one of them happens to slip; finally, the threads of  
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the warp and the woof, are now no longer so well defined, nor so distinct from each other, and the stuff being also thickened forms a warmer clothing.

Berthollet obtained a large proportion of acid of sugar by abstraction of nitreous acid from wool.

WORMS. See EARTH WORMS.

WORMWOOD. This vegetable affords a large quantity of vegetable alkali by incineration, which is the salt of wormwood of the shops. It does not differ from other alkalis when purified. The leaves of wormwood are intensely bitter, and have a strong and somewhat aromatic smell. They yield, according to Neumann, a considerable quantity of essential oil, possessing their whole smell, the bitter matter remaining in the extract.

## Y

Y E A

Y E A

**Y**EAST. The use of yeast in promoting the vinous fermentation appears to be in some respect that of rendering the process more uniform through a considerable mass. But the chief efficacy of its action does not seem to be well understood. Bodies remain unchanged so long as the elective attractions are satisfied or in equilibrio. Chemical operations are effected in no other way than by disturbing this state of repose, which may be done, either by mere change of temperature, or by the addition of some other principle. Thus an ignited coal may be considered as the ferment by which a large quantity of combustible matter may be made speedily to change its state of combination throughout. And so likewise it may be conceived, at least hypothetically, that the addition of a body considerably changed by the fermentative process may hasten the commencement of a similar change in a larger mass. See FERMENTATION.

## Z

Z A F

Z A F

**Z**AFFRE, or SAFFRE, is the residuum of cobalt, after the sulphur, arsenic, and other volatile matters of this mineral have been expelled by calcination. It is therefore a calx of cobalt, of a gray or reddish colour. The use of cobalt is to produce a very fine blue colour, when it is melted with fusible and vitrifiable matters.

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The calx of cobalt is the sole cause of the blue colour produced by zaffre. But as the quantity of regulus contained in cobalt is variable, some zaffres furnish more blue than others. The heterogeneous fixed matters contained in cobalts contribute likewise according to their quantity to the greater or less intensity of the blue colour. For this reason the manufacturers of zaffre from cobalt make frequent essays of the roasted ore, by mixing it with vitreous matters, to discover the intensity and beauty of the blue colour.

Good cobalt calcined would form too deep a blue, and almost a black glass, if it were not previously mixed with a certain quantity of vitreous fritt. In the manufacture of zaffre, therefore, the calx of cobalt, the strength of which has been previously determined by essays, is mixed with such a quantity of sand, or of powdered flints and quartz, that with the addition of some saline flux a deep blue glass may be formed.

The zaffre that is commonly sold, and which comes from Saxony, is a mixture of calx of cobalt with some vitrifiable earth. It is of a gray colour, as all the calces of cobalt are before vitrification. Some zaffres are dearer than others, according to the intensity of the colour which they are capable of producing. Zaffre is employed in the manufacture of pottery and of porcelain, for painting the surface of the pieces of ware, upon which it is applied together with some saline flux, previously to the baking or glazing, that the same fire may also vitrify this colouring material.

The blue of zaffre is the most solid and fixed of all the colours that can be employed in vitrification. It suffers no change from the most violent fire. It is successfully employed to give shades of blue to enamels, and to the crystal glasses made in imitation of some opaque and transparent precious stones, as the lapis lazuli, the turquois, the sapphire, and others of this kind. See AZURE; COBALT; INK, SYMPATHETIC; and SMALT.

**ZEOLITE.** This stone was unknown to mineralogists before the celebrated Cronstedt gave a description of it.

It is usually of a semi-transparent white; but this colour is sometimes altered by metallic mixtures, and then it assumes all kinds of tinges.

The name of zeolite has been given to it on account of its property of forming a jelly with acids. This property has even been considered as exclusive and characteristic. But Mr. Swab has very justly observed, in the year 1758, that all zeolites do not possess this property; and Mr. Pelletier has proved, in the xxth volume of the *Journal de Physique*, that this property is not even peculiar to zeolites.

The existence of zeolites in certain lavas has induced some naturalists to consider them as produced by the decomposition of volcanic earths.

The most beautiful zeolites come to us from the islands of Ferroe near Iceland. The form of this stone is constant. The radii which compose it diverge as it were from a central point, and are disposed after the manner of a fan. The radii which terminate at the external surface, are found to exhibit a trihedral or tetrahedral pyramid.

The white zeolite affects two principal forms, the cubic and the tetrahedral prism, sometimes flattened and terminated by an obtuse tetrahedral pyramid.

Its specific gravity is from 2.1 to 3.15.

The zeolite, exposed to a strong heat, dilates, and swells more or less, according



according to the proportion of water it contains, and at length melts into a porous scoria. Soda fuses it with effervescence; the borate of soda dissolves it more difficultly; and the phosphates of urine have scarcely any action upon it.

Bergman obtained from one hundred parts of the red zeolite of Adelfort, 83 filix, 9.5 clay, 6.5 pure lime, and 4 water.—*Letters on Iceland*, p. 370.

The white zeolite of Ferroe contains, according to Pelletier, 50 filix, 20 clay, 8 lime, and 22 water.—*Journal de Physique*, tom. xx.

Meyer obtained from a radiated zeolite 58.33 filix, 17.5 clay, 6.66 lime, 17.5 water.

Kirwan observes, that the crystallized species contain more water than the others.

ZINC is a semi-metal, of a blueish white colour, somewhat brighter than lead; of considerable hardness, and so malleable, as not to be broken with the hammer, though it cannot be much extended in this way. It is very easily extended by the rollers of the flattening mill. When broken by bending, its texture appears as if composed of cubical grains. On account of its imperfect malleability, it is difficult to reduce it into small parts by filing or hammering; but it may be granulated, like the malleable metals, by pouring it when fused, into cold water; or, if it be heated nearly to melting, it is then sufficiently brittle to be pulverized. It melts long before ignition, at about the 700th degree of Fahrenheit's thermometer; and, soon after it becomes red-hot, it burns with a dazzling white flame, of a blueish or yellowish tinge, and is calcined with such rapidity, that it flies up in the form of white flowers, called the flowers of zinc, or philosophical wool. These are generated so plentifully, that the access of air is soon intercepted; and the combustion ceases, unless the matter be stirred, and a considerable heat kept up. The white calx of zinc is not volatile, but is driven up merely by the force of the combustion. When it is again urged by a strong heat, it becomes converted into a clear yellow glass. If zinc be heated in closed vessels, it rises without decomposition. Zinc appears to be the most volatile of metallic substances except the regulus of arsenic.

The diluted vitriolic acid dissolves zinc: at the same time that the temperature of the solvent is increased, and much inflammable air escapes, an undissolved residue is left, which consists of plumbago. The theories of this solution, and the disengagement of inflammable air, are perfectly similar to those which have been before explained in the article IRON. As the combination of the vitriolic acid and the calx proceeds, the temperature diminishes, and the vitriol of zinc, which is more soluble in hot than cold water, begins to separate, and disturb the transparency of the fluid. If more water be added, the salt may be obtained in fine prismatic four-sided crystals. The white vitriol, or copperas, usually sold, is crystallized hastily, in the same manner as loaf-sugar, which on that account it resembles in appearance: it is slightly efflorescent. The white calx of zinc is soluble in the vitriolic acid, and forms the same salt as is afforded by zinc itself.

Diluted nitrous acid combines rapidly with zinc, and produces much heat, at the same time that a large quantity of nitrous air flies off. The solution is very caustic, and affords crystals by evaporation and cooling, which slightly detonate upon hot coals, and leave a calx behind. This salt is deliquescent.

Marine

Marine acid acts very strongly upon zinc, and disengages much inflammable air: the solution, when evaporated, does not afford crystals.

Water impregnated with fixed air dissolves a considerable proportion of zinc. The other acids have not been tried.

Zinc is precipitated from acids by the soluble earths and the alkalis: the latter re-dissolve the precipitate, if they be added in excess.

Zinc decomposes, or alters, the vitriolic neutral salts in the dry way. When fused with vitriolated tartar, it converts that salt into liver of sulphur; the zinc at the same time being calcined, and partly dissolved in the hepar. In this operation, the vital air of the acid combines with the zinc, and calcines it; at the same time that, according to the ancient theory, the phlogiston of the metal combines with the acid base, and converts it into sulphur. In the new theory, the transition of phlogiston is considered as hypothetical and unnecessary: because the metal and the sulphur being taken to be simple substances, the vitriolic acid becomes sulphur, merely by the loss of its vital air; and the zinc becomes calcined, merely by the acquisition of the same substance.

When pulverized zinc is added to fused nitre, or projected together with that salt into a red hot crucible, a very violent detonation takes place; in so much that it is necessary for the operator to be careful in using only small quantities, lest the burning matter should be thrown about. The zinc is calcined; and part of the calx combines with the alkali, with which it forms a compound soluble in water.

Zinc decomposes common salt, and also sal ammoniac, by combining with the marine acid. The filings of zinc likewise decompose alum, when boiled in a solution of that salt, probably by combining with its excess of acid.

Sulphur, though its action is almost general on metallic substances, does not combine with zinc. This property affords a ready means of purifying the semi-metal, by projecting sulphur upon it, when melted in a shallow crucible. It has been a subject of remark among chemists, that many of the zinc ores consist of this semi-metal combined with sulphur, though art has not yet discovered the means of effecting the same combination. But the difficulty is removed by the consideration, that the sulphur does not unite with zinc itself, yet it readily does with its calx, and forms a compound similar to the zinc ores, called blendes; in which, for that reason, the zinc may be presumed to exist in the calciform state.

Liver of sulphur does not combine with zinc, either in the humid or dry way.

Most of the metallic combinations of zinc have been already treated of. It forms a brittle compound with antimony; and its effects on manganese, wolfram, and molybdena, have not yet been ascertained.

Native zinc has been very seldom found. The calciform ores of zinc are the zinc spar, of a whitish gray colour, resembling a lead spar; and the impure calx called calamine, which is of a white, gray, yellow, brown, or red colour, containing iron, clay, calcareous and other earths, and lead. The ore called blende, mock-lead, or black-jack, consists of zinc mineralized with sulphur and iron: of this there are several varieties. They are in general of a plated texture, and frequently of a quadrangular form, like galena, or potters' lead ore, though they are considerably less heavy. These ores are found in various parts of Europe, and in considerable plenty in the mine counties of England. See ORES.



Native zinc may be assayed, in the humid way, by the mineral acids. When it is dissolved in these, if there be any other metal present, it may be precipitated by the addition of a known quantity of zinc. The weight of calx of zinc precipitated by mild alkali from its vitriolic solution, will amount to 193 grains for every 100 of the metal it represents. The sulphureous zinc ores must be carefully treated with nitrous acid; which will dissolve the zinc, and leave the sulphur. Extraneous metals may be precipitated, and the quantity of zinc ascertained, as before.

The essay of calamines is sometimes made by pounding and mixing them with charcoal, and then heating them in a crucible covered with a copper plate. The reduced zinc rises, and converts the copper into brass; and in this way some judgment may be formed of its value in the operation of brass-making. Most of the zinc, whether in the metallic state or in the form of an impure calx, called *cadmia fornacum*, is obtained in the roasting of various kinds of ores at Ramelsberg. For this purpose the interior part of the furnace is kept cold by wetting it: by which means the volatilized zinc is condensed, and falls into a cavity, containing charcoal dust, which defends it from calcination.

The process for obtaining zinc from its ores by distillation, which is practised in England, and said to have originally been derived from the Chinese, is performed in a furnace in the form of a circular oven; in which are placed six pots, each about four feet in height, and of a conical shape, resembling an oil-jar. Into the bottom of each pot an iron tube is inserted, which passes through the floor of the furnace into a vessel of water. These pots are filled with a mixture of calamine and charcoal; and their mouths are then close stopped with clay. The fire being then properly applied, the metallic vapour of the calamine issues through the iron tube, which is the only place where it can escape. In this way it is condensed into small particles in the water; which are afterwards melted into ingots for sale, under the name of *spelter*. The substance sold in London by the name of *spelter*, is a kind of soft brass, in a granulated form, which is used by the braziers and others for soldering.

The chief purpose to which zinc is applied consists in the fabrication of brass and other gold-coloured mixtures. Its calces and salts have been occasionally employed in medicine.

Dr. George Fordyce made an experiment by dissolving zinc in the vitriolic acid, and precipitating it by an alkali. The object was to ascertain from the weights of the metal, the calx, and the neutral salt produced, whether any of the acid entered into the composition of the calx, or of the inflammable air. As the quantity of acid was found to be undiminished, the strict consequence will be, that the additional weight of the calx comes from the water, which must have combined either in whole or in part with the metal, and that the inflammable air which escapes is produced either by the water or the metal. But as it is ascertained from other experiments that the calx contains vital air, this principle should appear to be one of the constituent parts of the water, and consequently the inflammable air will be the other. As this experiment appears to possess peculiar accuracy, and is of great importance relative to the theory of phlogiston, and the composition of water, I shall give the account nearly in the Doctor's own words\*.

\* Philosoph. Transf. for 1792, p. 375.

He took a portion of zinc and dissolved it in vitriolic acid, with which it made a clear solution (without any of that black matter which commonly separates during its solution when we employ zinc imported from abroad). After precipitating it by an alkali, and exposing the calx to the air, it remained of a pure white; so that it could contain no iron. This zinc was reduced to its perfect metallic form by breaking it into small particles, and melting it with black flux, taking that part of it only which was at the bottom of the crucible.

He reduced this metal to a calx, by dissolving it in vitriolic acid diluted with water, and precipitated it by kali purum dissolved in water.

In doing this the acid should be diluted with four or five times its weight of water, and the zinc should be dissolved very slowly, avoiding heat as much as possible during the solution. If this precaution is not taken, a quantity of volatile vitriolic acid will be produced, and spoil the experiment.

In the precipitation the alkali is apt to re-dissolve the calx, if care be not taken to use it in solution in water, and that the solution is diluted with a large quantity of water: the proportion in which the water is in aqua kali puri of the London Dispensatory is a convenient solution of the alkali.

Care must likewise be taken, in the precipitation, that the solution of the kali be poured into the solution of the zincum vitriolatum in water by a little at a time, and that the whole be perfectly mixed together before a fresh quantity is poured in; otherwise part of the calx will be re-dissolved. It is farther necessary that the exact quantity of kali purum be used: if too little is used, the whole calx will not be separated; if too much, part of the calx will be re-dissolved. It is also necessary that the alkali be perfectly pure, especially free from fixed air, as that would be transferred to the calx; and as it flies off when the kali is simply united with vitriolic acid, the accuracy of the experiment would be thus destroyed.

The weight of the calx, by which it exceeds the weight of the metal, shews that there is a substance added to the whole metal; or that, while some substance is driven off, another is added in greater quantity; since it is clear, from various experiments, that all matter gravitates, and that all the substances found on this earth, which have been tried, gravitate equally. This additional matter must be added to the metal either from the acid, the alkali, the water used in the solution, the air lying on the surface of the materials during the time of the operation, or it must come through the vessels in which the operation is performed. To ascertain this, he made the following experiment.

He took a large quantity of vitriolic acid, purified by distillation (about two pounds, it not being material what quantity was taken exactly); he diluted it with distilled water about four or five times its weight by guess (the exact proportion being also immaterial); he applied to 1000 grains of this diluted acid a sufficient quantity for saturation of aqua kali puri, of the London Dispensatory, rendered pure from fixed air, as is prescribed in the process of the College; he poured in the aqua kali puri to the diluted acid, by a little at a time, till it was nearly saturated. He then poured in some juice of violets, which gave the whole a red colour. He continued to add aqua kali puri, by a little at a time, till the red colour just disappeared. He added the aqua kali puri to the acid, rather than the acid to the alkali, because the loss of the red colour at the point of saturation can be discerned much better than the loss of the yellow colour, which the alkali intermixes with the natural hue.



He ascertained the weight of the aqua kali puri, by weighing the bottle containing it before any was poured into the acid, and after the saturation took place; the deficiency of weight afterwards being the weight of the aqua kali puri applied to the acid for the saturation; this was 10147 grains. He also weighed the vessel with the acid before the aqua kali puri was poured in, and afterwards; and found the increase of weight to be exactly the same as the weight of the aqua kali puri and juice of violets, so that nothing was lost during the operation.

This experiment was three times repeated, taking the point of saturation from the eye. The quantities of aqua kali puri employed were found to be 10147 grains, 10145 grains, 10150 grains.

He took 10148 grains, being the mean of the three experiments, and applied it to 1000 grains of the same vitriolic acid; evaporated the water to dryness, and heated it to a red heat, to drain off the whole of the water; and found 978 grains of kali vitriolatum remaining. By this means he ascertained the quantity of kali vitriolatum produced from 1000 grains of the diluted vitriolic acid, when saturated with kali.

He took 1000 grains of the diluted vitriolic acid, and put it into a vessel consisting of a spherical bulb of glass, with a neck or tube which communicated with another spherical bulb on the opposite side of which was also a neck or tube. The figure of this double bottle or vessel will be more readily apprehended, if, with the exception of its being much larger, the reader imagine a thermometer to have two bulbs, the one at the extremity of the tube, and the other a little higher up; the portion of the tube, left between the two bulbs, being in a line with the other portion of the tube, which constitutes the real neck or aperture of the whole vessel. The vitriolic acid was conveyed by means of a funnel into the lower globular part, and zinc was added until it would dissolve no more. During the solution the inflammable air was caught, which weighed nine grains, and was nearly twelve times as light as atmospheric air. The lower bulb was sufficiently capacious to contain the whole of the acid and zinc, and to admit of the compound bottle being laid on its side without the fluid running from the one part into the other. Dr. Fordyce denominates the outer globe A, the inner globe B, the tube of communication between them C, and the neck or tube into which the materials were admitted D.

The solution was terminated in five days; when part of the tube D being broke off, it was left to stand for four-and-twenty hours, to allow the inflammable air remaining in the vessel to fly off, and give place to the air of the atmosphere; which happened spontaneously from the different specific gravities of the two vapours.

The vessel containing the solution of the zinc was now laid upon its side, and 10148 grains of aqua kali puri were introduced by a crooked funnel into the globe B, being the quantity sufficient to saturate 1000 grains of vitriolic acid, as before determined. Then the tube D was hermetically sealed, and the whole weighed. The vessel was then raised, so that the globe A was undermost; this was done very gradually, so that the aqua kali puri was gradually added to the solution of the zinc; when a little was poured in, the vessel was brought into an horizontal position again, and shaken a little; this was repeated till the whole of the aqua kali puri was poured in. The zinc was thus precipitated in the form of a calx. It was suffered to stand for forty-eight hours; no alteration of the weight had taken place; therefore nothing had entered through the glass to give additional weight to the zinc in order to calcine it.

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The next step was to open the tube, which was done under water, and in an atmosphere of the same heat in which it was sealed, to wit,  $57^{\circ}$  of Fahrenheit's thermometer. The air was neither diminished nor increased, none of the water being driven into the apparatus by the weight of the atmosphere, and none being thrown out. On heating the globe B, so as to drive out some of the air, it was found to be of the same purity nearly as that of the atmosphere, being tried by the application of nitrous air produced from solution of mercury.

The weight therefore, which the calx had gained, arose neither from any substance passing through the glass, nor from the superincumbent air during the precipitation. It must therefore be either from the acid, the alkali, or the water.

To determine whether the acid or alkali gave the weight to the calx of the zinc, he washed out the kali vitriolatum, formed by the combination of the vitriolic acid and the kali, with pure water repeatedly applied, until it came away as pure as when applied to all sensible trials. The quantity of water used was above four pounds. He evaporated this water to dryness, and heated the mass red hot, to expel the whole of the water; it weighed seven grains more than the vitriolated tartar procured from applying the acid and alkali as above. After evaporating the water, he dissolved the mass again in 40 ounces troy weight of pure water; a yellowish powder separated. The solution of the vitriolated tartar, cleared of this powder, was again evaporated to dryness, and the water of crystallization driven off. It now weighed  $976\frac{1}{2}$  grains, which is barely two grains less than the vitriolated tartar he obtained from the acid and alkali applied simply together, without the intervention of the zinc.

The vitriolated tartar now obtained was free from any mixture. The additional weight of the calx of the zinc did not arise therefore from either the acid or the alkali; it remains therefore, that it arose from the water.

The weight of the calx of the zinc was ascertained by drying it after washing out the vitriolated tartar, heating it to a red heat, and afterwards weighing it. The weight of the zinc dissolved in saturating the acid was 164 grains: the weight of the calx 220 grains. The additional weight was therefore 56 grains.

If it arose from the water, then a quantity of water, equal to the weight by which the calx exceeds the metal, must be lost in the operation. To determine this, he performed a distillation in the following manner:

He put 1000 grains of the same diluted vitriolic acid into the globe A of the same apparatus, then introduced the quantity of aqua kali puri found necessary to saturate it. The tube D was then bent downwards about the middle, and the apparatus brought to an horizontal position; so that the bent part of the tube was in a perpendicular direction downwards: to this he affixed a small phial, and weighed the whole. He then put the globe B in a box filled with ice, and applied heat to the globe A, so as to distil over the water into the globe B, the liquor never being brought to the boiling point. When the matter in the globe A became dry, the heat was increased to a red one, to distil over likewise the water of crystallization. The whole apparatus was now weighed, and found not to have lost a grain; nor was there any water in the phial. He then cracked the tube C, by applying a red hot iron to it, and letting a drop of cold water fall upon it. He next weighed the globe B with the water in it, then poured out the water, and let the glass dry. He weighed the glass; the

deficient



deficient weight from the former weighing, being the weight of the water, was 10098 grains.

He repeated the experiment with this difference: he put 1000 grains of the same vitriolic acid into the globe A, then introduced the quantity of zinc sufficient to saturate it: he took the weight of the inflammable air as before, and found it nearly the same in weight and quality. The same quantity of aqua kali puri was then introduced through a funnel as in the former experiment, then the tube was bent downwards, and a phial applied to it as before. The whole apparatus was weighed after the distillation, and found not to have lost any sensible quantity of weight, nor was there any water in the phial. The phial being detached, and the tube broken as before, the globe weighed again when dry, the deficiency was less than in the former experiment by 63 grains, which is two grains less than the additional weight of the calx above the metal and the inflammable air taken together; and therefore Doctor Fordyce concludes that matter occasioning the additional weight of the calx above that of the metal and the inflammable air are both produced from the water.

TABLE.

## A P P E N D I X.

**I**N the following tables of chemical compounds, the reader is presented with a view of as much as could be collected, with considerable industry, of their ingredients and general properties. It is unnecessary to insist on the extreme utility which might result to the practical as well as philosophical chemist, if these could have been ascertained to the utmost accuracy of weight, measure, and purity. Much advantage may nevertheless be derived from them in their present imperfect state, which is capable of great and daily improvement. Every practical chemist may benefit both himself and others, by carefully tabulating in this manner such results as he can depend on; for much of experimental labour would be spared to every active cultivator of this science, if it were possible, for the most part, to extract from tables such documents as might nearly foretell what would happen in any projected experiment. These tables will point out to the student what departments more particularly require cultivation. The present limits necessarily excluded an insertion of the authorities, and various other interesting particulars; which are indeed the less necessary, because the whole demands an assiduous experimental examination. A philosopher, in the fortunate circumstances to prosecute so arduous an undertaking; in possession of all the materials in their utmost purity, of the knowledge to perform it with effect, and of the spirited attachment to science to apply his time to this pursuit, would do infinitely more service to society, than the inventors of a multitude of theories.

The tables require no other explanation than that the substance or principle in any horizontal compartment, united with the substance or principle at the head of any column, will form the compound described in the square, common to both.



Simple Principles.	Vital air.	Azotic air.	Inflammable air.	Basis of fixed air.	Sulphur.
Vital air.					
Specific gravity 1,36.					
Azotic air.	Atmosf. air by mixture. Nitrous air by combin. Nitrous acid. Aeriform. Aqueous solution.				
Specific gravity 1,19.					
Inflammable air.	Water? Sp. gr. 1000.	Mixture. Volatile alkali. Aeriform sp. gr. 0,73. Aqueous sol. Spirituos sol.			
Specific gravity 0,09.					
Basis of fixed air. Pure charcoal?	Aerial acid, or fixed air. Aeriform sp. gr. 1,84. Aqueous solution. Spirituos solution.	Qu.	Heavy inflam. air. <i>Ardent spirit?</i>		
Sulphur.	Vitriolic air. Sp. gr. 1,88 Aqueous solution, or sulph. acid. Vitriolic acid. Aqueous crystallized. — liquid.	Qu.	Hepatic air. Aeriform. Aqueous sol. Spirituos sol.	Qu.	
Phosphorus.	<i>Phosphoreous acid?</i> Phosphoric acid. Dry or glacial. Aqueous solution. <i>Spirituos solution?</i>	Qu.	<i>Phosphoric air?</i>	Qu.	Inflammable compound.
Veg. alkali.	Qu.	Qu.	Qu.	Qu.	Hepar. Aqueous solution.
Solid.					
Aqueous solution. Spirituos solution.					
Min. Alkali.	Qu.	Qu.	Qu.	Qu.	Hepar. Aqueous solution.
Solid.					
Aqueous solution. Spirituos solution.					
The earths.	Qu.	Qu.	Qu.	Qu.	Hepars.
Solid.					
Metals.	Calces.	Qu.	Qu.	Plumbagos. Qu. other compounds.	Ores.
Solid malleable.					
Bases of acids, not hitherto exhibited in a separate state.	Acids, with one or more bases, and different proportions of vital air.	Qu.	Qu.	Qu.	Qu.

have not been hitherto decomposed.

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Phosphorus.	Veg. alkali.	Mineral alkali.	The earths.	Metals.
Hepar.				
Hepar.	Mixture.			
Hepar.	Aqueous combination and in the dry way glafs.	Aqueous combination and in the dry way glafs.	Glaſs.	
Ores.	Qu. direct. Indirect combination by precipitation. But not unless calcined?	Qu. direct. Indirect as with vegetable alkali.	No direct combination. Indirect as with veg. alk.?	
Qu.	Qu.	Qu.	Qu.	Qu.



TABLE II. *Compounds consisting in general of*

Component Parts.	Veget. alkali. Deliquescent. Aqueous solution. Spirituos solution.	Mineral alkali. Deliquescent. Soluble in water. — in ar. sp.	Volatile alkali. Aeriform. Soluble in water. — in ar. sp.	Vitriolic acid. Aeriform? Aqueous, crystallizable. Sp. gr. 2,125 at most. Sp. gr. 2,00, Kirwan's standard.	Sulphureous acid Aeriform, but conden- sible by extreme cold. Aqueous solution.
Siliceous earth. Pure white powder taste- less. Sp. gr. 2,6. Insoluble in water or ardent spirit. Infusible?	With water. Liquor of flints. Deliquescent? In the dry way glass.	With water. Liquor of flints. Deliquescent? In the dry way glass.	No direct union.	No direct union.	No direct union.
Calcareous earth. White powder. Sp. gr. 2,3. Caustic taste. Heats with water, and dissolves in 680 times its weight. Acts slightly on ard. spi. Infusible.	With water? In the dry way glass.	As the veg. alk.?	Qu.?	Selenite, gypsum, or plaster. Crystalliz. permanent. Sp. gr. about 2,3. Soluble in 500 parts of water. 32 parts earth. 47 acid? 21 water?	Combination. Saline? or becoming so by exposure to the air?
Argillaceous earth. White powder tasteless. Sp. gr. about 2,0. Forms an adhesive paste with water, but is not soluble in less than 7,000 times its weight. Insol. in ar. sp.? Infusible, but contracts and hardens by heat.	With water no action? In the dry way glass?	As the veg. alk.?	Qu.?	Alum. Perm. cryst. if alk. be pre- sent, and acid in excess. Soluble in 15 p. water. 18 parts earth. 30 acid? 52 water? If the excess of acid be sat. with alk. the earthy salt becomes almost inf.	Combination?
Magnesian earth. White powder. Sp. gr. 2,33. Not more soluble in wa- ter or ard. sp. than argil. earth. Infusible.	With water? In the dry way?	As the veg. alk.?	Qu.?	Epsom salt. Bitter efflorescent cryst. Soluble in 1 p. water. 20 earth. 35 acid? 45 water?	Combination. Saline?
Ponderous earth. White powder, caustic taste. Sp. gr. 4,00? Soluble in 900 times its weight of water. Infusible.	With water? In the dry way?	As the veg. alk.?	Qu.?	Ponderous spar. Permanent crystals. Sp. gr. 4,47. Insoluble in water or ar. sp. 84 earth. 16 acid. 0 water?	Combination??
Veg. alkali. White, concrete, deli- quescent, caustic taste. Very soluble in water. Sol. in ar. sp.		Mixture.	Mixture.	Vitriolated tartar. Small permanent crystals. Soluble in 16 p. water. 53 alkali. 41 acid? 6 water?	Stahl's sulphureous salt. Crystals permanent. Pungent taste. Soluble in less water than vitriolated tartar, into which it becomes chang- ed by exposure to the air.
Mineral alkali. White, concrete, deli- quescent, caustic taste. Very soluble in water. Sol. in ar. sp.	Mixture.		Mixture.	Glauber's salt. Large efflorescent cryst. Soluble in 3 p. water. 16 alkali? 26 acid? 58 water?	Saline combination, re- sembling Stahl's sul- phur. salt?
Volatile alkali. Aeriform, pungent smell and taste. Soluble in water. — in ard. sp.	Mixture.	Mixture.		Vitriolic ammoniac. Permanent crystals. Soluble in 2 p. water. 56 alkali?? 31 acid? 13 water? Volatile or decomposable by heat?	Saline combination?

Nitrous acid. Aeriform. Aqueous sp. gr. 1,580. Kirwan's stand. Aeriform with excess of azotic air, that is co- loured nitrous acid. — or with maximum of azotic air, viz. nit. air. No direct union.	Marine acid. — aeriform. — aqueous sp. gr. 1,195. Kirwan's stand. sp. gr. 1,5. No direct union.	Aerated marine acid. Aeriform. Aqueous solution. No direct union.	Nitro-muriatic acid. Aeriform? Aqueous. No direct union.	Phosphoric acid. Dry, deliquescent. Aqueous solution. No direct union in the humid way; but it cor- rodes glass with heat. In the dry way glassy or glacial acid, tasteless, and not deliquescent?	Aerial acid, or fixed air. Aeriform. Aqueous solution. No direct union.
Nitrated lime. Deliquescent crystals. Sol. in 2 p. water, and in 7-10th p. ar. sp. 32 earth. 43 acid. 25 water?	Muriated lime. Deliquescent crystals. Sol. in 2 p. water, and in 7-10th p. ar. sp. 40 earth? 34 acid? 26 water??	Saline combination?	Triple salt??	Phosphorated lime, or earth of bones. Scarcely soluble in water, unless by excess of acid.	Chalk. spar. Insoluble, infusible. 55 earth. 34 fixed air. 11 water.
Nitrated clay. Small deliquescent cry- stals, styptic taste.	Muriated clay. Small deliquescent styptic crystals.	Saline Combination?	Triple salt??	In the dry way the gla- cial acid by strong fu- sion? In the humid way. Qu.?	Lac lunæ?
Nitrated magnesia. Deliquescent cryst. acrid and bitter. Very soluble in water and in ar. sp. 27 earth. 43 acid. 30 water?	Muriated mag. Deliquescent? crystals? bitter acrid. Very sol. in water, and in ardent spirit. 41 earth. 34 acid. 25 water.	Saline combination?	Triple salt??	Saline compound. Soluble in excess of acid, crystalliz. Not soluble in ar. sp.	Aerated magnesia. Efflorescent cryst. nearly tasteless. Soluble in 40 p. water. Insoluble in ar. sp.? 50 earth. 25 acid air. 25 water.
Nitrated p. earth. Of difficult solubility. Deliquescent?	Muriated p. earth. Permanent crystals. Moderately soluble in water? Insol. in ar. sp.?	Saline combination?	Triple salt??	Qu.?	Aerated pond. earth. Insoluble native crystals. 78 earth. 20 acid. 2 vitriolated barytes.
Nitre. Permanent crystals, solu- ble in 7 p. water, and in 50 p. ar. sp. 12 alkali. 63 acid. 5 water. Detonates with combusti- ble matter.	Muriated veg. alkali, or salt of Sylvius. Permanent crystals. Sol. in 3 p. water and in 4 <sup>th</sup> p. ar. sp. 62 alkali. 32 acid. 6 water.	Aerated salt. Perm. cryst. silvery bril. Soluble in water. — in spirit? Comp. said to differ from salt of Sylv. only in the excess of vital air. Detonates with combust. more strongly than nit.	Nitre and salt of Sylvius? Or a triple salt??	Very soluble salts, diffi- cultly crystal.	Mild alkali. Permanent crystals if sa- turated. Very soluble in water. Insoluble in ar. sp.? 48 alkali. 20 acid. 32 water.
Rhombic nitre. Slightly deliques. cryst. Soluble in 1-3d p. water? and in 13 p. ar. sp. 50 alkali. 28 acid? 22 water? Detonates with combust.	Common sea salt. Permanent crystals. Sol. in 3 <sup>1</sup> / <sub>2</sub> p. water. Insol. in ar. sp. 42 alkali. 52 acid. 6 water.	Aerated salt. Very deliquescent.	Rhombic nitre and com. salt? Or triple salt??	Soluble salt. Crystallizable with ex- cess of alkali. Efflorescent.	Mild alkali. Efflorescent crystals. 20 alkali. 16 acid. 64 water.
Nitrous ammoniac. Crystals; deliquescent? Sol. in 1 p. water, and in 1 p. ar. sp. 12 alkali? 80 acid? 8 water? Decomposed by heat with explosion.	Sal. ammoniac. Perm. cryst. not brittle. Sol. in 6 p. water, and in 12 <sup>1</sup> / <sub>2</sub> ar. sp. 40 alkali. 52 acid. 8 water. Sublimes entire in mode- rate heat.	Decomposition of the alk. Products. Common marine acid. Water? Azotic air.	Partial decompos. ? and triple salt? Or two distinct salts??	Soluble salt, crysalliz. with excess of alkali; but disposed to fly off in evaporation. If the excess be the min. alk. it is the micro- cosmic salt.	Mild vol. alkali. Slightly efflorescent cryst. 43 alkali? 45 acid? 12 water. Sublimes by gentle heat.



Component Parts.	Acid of borax. Permanent crystals. Sol. in 20 p. water, and in less ar. spirit. Rises with boiling water, but not alone.	Acid of fluor. Aeriform. Aqueous solution. Spirituos ?	Acid of ambr. Concrete sublimate. Soluble in 24 p. water, and in about 3 ar. spirit.	Acetous acid. Aeriform. Aqueous. Aqueous aerated or radi- cal.	Acid of tartar. Permanent crystals. Aqueous solution.
Siliceous earth.	In the dry way. Glass opaque and frothy.  Humid way. Dissolves the earth preci- pitated from an alkali line solution.	Aeriform solution. Deposits earth when passed thro' water.  Humid way. Solution; crystallizable.	No action.	No action.	No action ?
Calcareous earth.	In the dry way. Friable combination.  Humid way. Solution.	Natural compound, or fluor spar.  Gelatinous solution. Regenerated fluor.	Permanent crystals of ve- ry difficult solubility.	Acetated lime. Permanent crystals. Not soluble in ar. sp. 36 earth. 58 acid. 6 water. Mere distillation destroys the acid.	Salt of very difficult solution. Tartarized lime.
Argillaceous earth.	In the dry way. Hard gray mass.  Humid way. By trituration combina- tion of difficult solubi- lity.	Adhesive gelatinous so- lution.	Prismatic crystals not de- composable by alkalis.	Salt of difficult crystalli- zation.	Astringent solution. No crystals, but a clear gum-like mass by eva- poration. Soluble in water, but not deliques- cent.
Magnesian earth.	In the dry way. Combination.  Humid way. Irregular crystals. Ardent spirit deprives them of their acid.	Saline compound not so- luble in water but by excess of acid. Crystals soluble in ardent spirit. Not decomposed by heat, nor by any known acid.	Gummy saline deliques- cent mass.	Deliquescent gum-like mass. Soluble in ar. sp. gives out its acid by distil- lation.	Saline mass, soluble with excess of acid and crystallizable.
Ponderous earth.	Qu. ?	Scarcely soluble Salt in powder.	Qu.	Deliquescent salt.	Qu.
Vegetable alkali.	By fusion. Mass of a glassy appear- ance. By solution. Crystallizable salt.	Gelatinous solution. By evaporation foliated.	Deliquescent bitter crys- tals, very soluble in water. Qu. In ardent spirit ?	Acetated veg. alkali. Vulg. foliated tartar. Deliquescent. Soluble in ardent spirit. 50 alkali. 41 acid. 9 water. Mere distillation destroys its acid.	Crystals of tartar. Soluble in 48 p. water ? 23 alkali. 77 acid, of which 34 are in excess. Soluble tartar. Sol. in 5 p. water ? 23 alkali. 43 acid.
Mineral alkali.	Common borax. Permanent crystals, with excess of alkali. Soluble in 18 p. water. 17 alkali, of which 8 are excess. 34 acid. 47 water.	Gelatinous solution. By evaporation foliated.	Permanent bitter crystals soluble in about 5 parts water ? Q. Ard. spirit ?	Acetated min. alkali. Permanent crystals. Soluble in ardent spirit.	Rochelle salt. Crystals slightly efflor. This combination has al- so a period of less so- lubility with excess of acid, as happens with the veg. alkali.
Volatile alkali.	Soluble crystallizable salt.	Gelatinous solution. Deliquescent crystals.	Crystallized salt. Permanent ? Soluble in water and in ar. sp. Fusible and totally eva- porable.	Saline solution, called spirit of Mindererus. Rises by heat first pure alkali, then acid, then neutral sublimation.	Tartarized ammoniac. Crystallized. Soluble in water. Less soluble if the acid be in a determinate excess.

Emphyreumatic acid of tartar. Aqueous.	Acid of sugar, Crystallized. Soluble in 2 parts water, and in 2½ p. ar. spirit, also in ether and all oils.	Acid of galls. Crystals. Soluble in 24 p. water, and in 4 p. ar. spirit.	Acid of lemons. Crystals. Soluble in water and in ar. spirit.	Acid of apples. No crystals. Aqueous sol. Spirituous sol.	Acid of benzoïn. Concrete inflammable sublimate. Sol. in 500 p. water, in a few p. ar. spirit, and in oils.
No action.	No action?	No action.	No action.	No action.	No action.
Saline compound. Qu?	Insoluble compound. 46 earth. 48 acid. 6 water. Decomposed by fire, but by no acid yet known.	Soluble salt.	Salt of very difficult solution. Insoluble in ar. spirit.	Crystallized salt, Soluble in boiling water. Insoluble in ar. spirit.	Crystals of sparing solubility.
Compound?	Yellow astringent mals. Not crystallizable. 44 earth. 56 acid and water.	Qu.	Salt of difficult solution.	Salt of difficult solution.	Astringent salt.
Compound?	White saline powder. 35 earth. 65 acid and water.	Soluble salt.	Salt of difficult solution.	Deliquescent salt.	Crystall. salt. Easily soluble in water. In ardent spirit?
Compound?	Compound of difficult solubility. Crystalliz. with excess of acid.	Soluble salt.	Salt of difficult solution.	Crystall. salt, very sparingly soluble.	Qu.
Crystallizable and soluble compound.	Compound of difficult crystallization, unless one of the two principles be in excess. Soluble in water and in ardent spirit. If the acid be in a determinate excess, it forms salt of forrel.	Salt.	Deliquescent salt.	Deliquescent salt.	Deliquescent feather-like crystals.
Crystallizable and soluble compound.	Salt of sparing solubility. Crystalliz. Insoluble in ar. spirit.	Salt.	Deliquescent salt.	Deliquescent salt.	Efflorescent crystals.
Saline compound?	Crystallizable salt. Very soluble in water. Insoluble in ar. spirit.	Salt.	Salt, Deliquescent?	Deliquescent salt.	Small deliquescent crystals.



Component Parts.	Empyreumatic acid of wood. Aqueous solution.	Empyreumatic acid of sugar, &c. Aqueous solution. Spirituos solution.	Acid of camphor. Bitter crystals.	Acid of milk. Aqueous solution. Not crystallizable.	Acid of sugar of milk. White powder. Sol. in 80 p. water. Crystallizable. Inflammable.
Siliceous earth.	No action.	No action.	No action.	No action.	No action.
Calcareous earth.	Saline compound.	Soluble salt. Not crystallizable.	Qu.	Deliquescent salt.	Insoluble combination.
Argillaceous earth.	Qu.	Gummy astringent mass.	Qu.	Deliquescent salt.	Insoluble combination.
Magnesian earth.	Saline compound.	Gummy mass opaque, and hard when dry.	White pulverulent salt.	Crystall. salt. Deliques.	Insoluble combination.
Ponderous earth.	Saline compound.	Qu.	Qu.	Deliques. salt.	Insoluble combination.
Vegetable alkali.	Soluble salt. Crystallizable?	Crystalliz. salt. Of difficult solution. Insoluble in ar. spirit.	Crystallized salt.	Deliques. salt. Soluble in ar. spirit.	Crystalliz. salt, nearly insol. in cold water, but sol. in 8 p. boiling water.
Mineral alkali.	Soluble salt.	Crystalliz. salt. Very soluble in water. Insoluble in ar. spirit.	Crystall. salt.	Deliquescent salt. Sol. in ar. spirit.	Crystalliz. salt, nearly insol. in cold water, but sol. in 5 p. boiling water.
Volatile alkali.	Soluble salt?	Soluble salt. Not crystalliz.	Crystall. salt.	Deliques. salt.	Salt with excess of acid?

Acid of ants. Aqueous.	Prussian acid. Aeriform. Aqueous.	Acid of fat. Liquid, fuming.	Acid of the stone of the bladder. Concrete; sparingly so- luble; decomposed by heat.	Acid of silk worms. Aqueous.	Metallic Acids. Of arsenic. soluble in 2 p. water. Of tungsten. insol.
No action.	No action.	No action. Corrodes glass?	No action.	No action.	No action??
Permanent crystals, bitter taste. Soluble in 8 p. water. Insoluble in ar. sp.	Combination aqueous. Test liquor for iron.	Permanent crystals. Very soluble in water. Insoluble in ar. sp. 85 earth. 15 acid and water?	Combination of sparing solubility.	Qu.	Arfenical salt. Crystalliz.  Tungsten. insoluble. 2 earth. 1 acid or calx.
Combination difficultly effected.	No direct action. Nor indirect??	Astringent mass. Not crystalliz. Earth. Acid. Alkali??	Qu.	Qu.	Arfenical coagulum.
Salt of difficult solubility? Efflorescent? Insoluble in ar. sp.	Combination by a very weak action.	Gum-like mass. Not crystallizable. 8 earth. 2 acid and water.	Qu.	Qu.	Arfenical coagulum.
Permanent crystals, bitter taste. Soluble in 4 p. water. Insoluble in ar. sp.	Solution of a very small portion of the earth.	Qu.	Qu.	Qu.	Arfenical salt. Of diffic. solub.?
Deliquescent crystals.	Pure prussiated alkali. Crystallizable. With excess of acid?  Common prussian alkali, or lixivium sanguinis; contains more or less of iron in combination.	Permanent crystals. Segner's salt. Insoluble in ar. sp.	Yellow solution. Not crystallizable??	Qu.	Arfenical salts. Soluble in water. Crystall. with excess of alkali.  Tungstenic combin. Soluble with excess of alkali.
Foliated deliques. cryst. Soluble in 2 p. water.	Crystallizable salt.	Crystalliz. salt. Deliquescent??	Solution. Crystalliz.?	Qu.	Arfenical neutral salt. Crystals.  Tungstenic?
Extremely deliquescent crystals.	Saline compound. Crystallizable? Rises entire by distilla- tion; Without decomposition?	Crystalliz. salt. Sublimable without de- compos.?	Solution. Alkali much. Acid little.	Qu.	Arfenical salt. Crystalliz.  Tungstenic salt. Crystals with excess of alkali.



Component Parts.	Vegetable alkali.	Mineral alkali.	Volatile alkali.	Vitriolic acid.	Sulphureous acid.
<b>Calx of Gold.</b> Yellow metal, but green by transmitted light, or when fused; very malleable and tenacious; not calcinable by fire; does not rust. Specific gravity 19,3.	No direct action. Solution of precipitate from acid?	As the vegetable alkali.	No direct action on the metal. Precipitates from acid, and combines with it. Fulminating gold.	No action on the metal. Slight action after previous distil. of the acid from manganese.  Precipitates by F. alkali. Soluble but weakly retained.	No action?
<b>Calx of Platina.</b> White metal malleable, very difficult of fusion, does not rust; capable of welding. Specific gravity 22,0. Or 24,0?	No direct action. Throws down a precipitate from acid, consisting first of a triple crystal. salt, and next of a calx.	No direct action. Precipitates a calx from acid.	No direct action.  Precipitates from acid similar to the vegetable alkali.	No action?  Precipitate from nitromuriatic solution.	No action.
<b>Calx of Silver.</b> White metal, very malleable, scarcely calcinable by furnace, does not rust; becomes black from sulphur. exhal. Specific gravity 10,5.	No direct action.	No direct action.	No direct action.  Combination with the calx precip. from nitrous a. by lime water. Crystalliz fulmin. silver. Extremely dangerous.	Calcination by boiling and sparing solution. Small crystals.	Qu.
<b>Calx of Mercury.</b> White metal, solid, and mall. when cooled below $-39^{\circ}$ ; fluid in all higher temp. boils and rises without decomp. at $600^{\circ}$ ; cal. in a mod. heat, and red. without ad. by a greater heat. Specific gravity 13,6.	Qu.	Qu.	Qu.	Solution by heat, mostly separated in form of white calx. Crystals, vitriol of mercury. Both the calx and the cryf. become yellow by wash. off the ac. with b. water. Turbith mineral.	Qu.
<b>Calx of Tin.</b> Yellowish white metal. Malleable, fusible at $410^{\circ}$ ; calcinable, does not rust, acidifiable. Specific gravity 7,3.	Qu.	Qu.	Qu.	Solution and separation of calx, especially if the acid be concent. and hot. Crystals, by cooling.	Qu.
<b>Calx of Copper.</b> Reddish brown metal; hard; sonorous malleable; tenacious, fusible by strong heat, burns with blueish green flame; partly vol. by ebull.; cal. and liable to rust.	Combin. in the dry way? In the humid way assisted by the air, Slight combination or corrosion.	As the vegetable alkali.	Sparing solution by the assistance of air and water. Crystals. Indirect combin. with precipitates.	Solution in boiling concent. acid. Crystal. after dilution. Sol. in 4 p. water. 27 copper. 30 acid? 43 water?	Qu.
<b>Calx of Lead.</b> Blue white metal; soft; malleable; fusible at 540 degrees; boils, and perhaps rises in close vessels; calcinable. Slightly rusts. Specific gravity 11,3.	In the dry way combination. In the humid way corrosion and solution.	As the vegetable alkali?	Qu.	Solution and calcination. Crystals. Sol. in 18 p. water. Or more?	Qu.
<b>Calx of Iron.</b> Gray white metal; hard; elastic; malleable; tenacious; very difficult of fusion; becomes ignited by blows; weldable; magnetic; calcinable; very liable to rust. Specific gravity 7,8.	Combin. with the calx by fusion. In the humid way, calcination and combin.	As the vegetable alkali?	Combination.	Solution with heat if concentrated, but in the cold if diluted. Efflor. crystals. 25 iron. 20 acid? 55 water?	Qu.

Nitrous acid.	Marine acid.	Aerated marine acid.	Nitro muriatic acid.	Phosphoric acid.	Aerial acid or fixed air.
Exceedingly sparing solution of the metal. Precipitates by f. alkali. Soluble, but weakly retained.	No action. Precipitates by f. alkali. Sol. but weakly retained.	Solution with effervescence. Crystals. deliques.	Solution with effervescence. Crystals, deliques. Containing marine acid only?	In the dry way by fusion purple combination. In the humid way no action on the metal. Reduces and precipitates from acid sol.	No action. Indirect combination?
No action.	No action.	Solution as with the nitro muriatic acid.	Solution very dark yellow or brown red. Crystals, red, very sparingly soluble.	No direct action. Reduction and precipitation from acid?	No action. Qu. indirect.
Rapid solution. Crystals. Lunar nitre, or lunar caustic, when fused. Soluble in water and in 2½ ar. sp. Extraction and decomposition of the acid by heat.	Very sparing solution? Precip. from nitrous acid. Luna. cornea. Fusible. Soluble in about 1000 p. boiling water.	Solution and precipitation of luna cornea.	Solution and precipitation of luna cornea.	No direct action. Acts on the calx or precipitate?	No action. Indirect comb. by precipitation.
Rapid solution. Crystals. Mercurial nitre. If heat be employed the quantity taken up is greater, and water throws down a yellow calx, resembling turbit mineral.	No direct action. Takes it from the nitrous solution, and falls down in the form of cor. sub. or calomel, as the mercury was more or less calcined.	Solution. Crystals. Corrosive sublimate. Sparingly soluble in water, and in ar. sp.	Solution and precip.? Corros. sublimate?	No action. Precipitation from nitric acid.	No direct action. Indirect comb. by precipitation.
Very rapid solution; most part calcined and precipitated. No crystals. Production of volatile alkali.	Solution. Permanent crystals.	Solution without effervescence. Permanent crystals. Indirect comb. by distilling amalgam with corrosive sub. Liquor of Libavius. Becomes solid with water.	Solution. The phenomena differ much according to the proportion and concentration of the acids, and the quantities of metal added at a time.	Corrosion of the metal and slight solubility of the calx.	No direct action. Indirect comb. by precipitation.
Rapid solution, some calx falls down. Crystals, by slow evap. Soluble in 4 p. water? And in 4 p. ar. sp.	Solution in concent. and boiling acid. Crystals.	Solution.	Solution.	Slight action on the metal. Assisted by the air?	No direct action? Indirect comb. by precipitation. And solut.?
Calcination, if concentrated. Solution, if more dilute. Crystals.	Calcination and partial solution. Crystals. Indirect combination. Corneous lead. Insol. in water?	Qu.	Qu.	Slight corrosion. Precipitation from nitrous acid? And from sugar of lead.	No direct action. Indirect comb. by precipitation. And solut.?
Solution. Deposition of calx. No crystals.	Solution. Magma. and deliquescent crystals.	Solution.	Solution.	Solution with effervescence. Crystalliz. or magma? Compound deposited by the addition of water. Siderite.	Solution. Separates in the form of an ochreous film. Also indirect comb. by precipitation.



Component Parts.	Acid of Borax.	Acid of Fluor.	Acid of Amber.	Acetous acid.	Acid of Tartar.
Calx of Gold.	No action either dry or humid: Nor indirect? Colour of the metal said to be changed by fusion.	No action on the metal. Precipitate dissolved.	Qu. No action.	No direct action on metal. Metallic precipitat. from solution. Precipitates by alkalis dissolved.	No action on the metal. Solution of precip.
Calx of Platina.	No action.	Qu. No action.	No action on the metal. Indirect?	No direct action on metal. Precipitates by alk. dissolved.	No action on the metal. Solution of precip.?
Calx of Silver.	No action?	No action on the metal. Partial solution of precipitate.	Solution of precipitate. Crystals.	No action on the metal. Precipitates by alk. dissolved with heat, crystallizable.	Solution of precip.
Calx of Mercury.	No direct action on the metal either dry or humid. Saturated borax throws down a yellow compound from nitrated mercury.	No action on the metal. Indirect combination. Solution of precipitate.	Solution of precipitate. Crystals??	No action on the metal. Calces and also precipitates dissolved. Shining crystals.	Imperfect combination, or Ethiops. Precipitates from nitrous sol. Other indirect combinations.
Calx of Tin.	Sparingly combinable in the dry and humid ways. White crystals.	No action on the metal. Gelatinous solution of precipitate.	Solution of precipitate. Crystalliz.	Slight solut. of the metal, not crystalliz. Precipitates and calces by deflagration are soluble. Crystals. Salt of Tin.	No action on the metal. Indirect action?
Calx of Copper.	Combination by fusion. Weak action by heat in the humid way. Saturated borax precipitates all acid solutions of copper. The compound is green, and almost insoluble.	Solution. Blue crystals.	Solution of the metal by long digestion. Crystalliz.	Sol. with vital air. Crystals of Verdigrise. With more calx. Common Verdigrise.	Little action on the metal. Acts on the calces. Precipitates vitriolic and marine solutions. Blue crystals, or Brunswick green.
Calx of Lead.	Fine greenish Glais by fusion of 1 p. acid and 2 p. minium. No humid action, but borax throws down this metal from acids.	Solution of the calx. Sweetish taste. No crystals, but a powder depof. by evapor.	No action of the metal. Indirect combin. Solution of precip. Crystalliz.	Solution crystalliz. Sweet taste. Sugar of lead. With more calx. Ceruse.	Precipitation from nitrous or marine acid. Solution of calces??
Calx of Iron.	Soluble compound by fusion. Amber coloured solution with water; crystalliz. Borax precipitates this metal from acids, and its acid dissolves the precipitates.	Strong action on the metal, and also its calces. No crystals, but hard mafs. by vapor.	Slight action on the metal. Solution of precip. Crystalliz.	Slight action on the metal. Solution deliquescent crystals. Acid decomposed by distil. or extricated?	Solution of the metal. Indirect combination by martial vitriol. Crystals.

Emphyreumatic Acid of Tartar.	Acid of Sugar.	Acid of Galls.	Acid of Lemons.	Acid of Apples.	Acid of Benzoïn.
Qu.	No action on the metal, nor its precip.	Precipitate in the metal- lic state from acid so- lution.	No action. Indirect ?	Qu.	Qu. Indirect ?
Qu.	No action on the metal. Solution of precip. Yellow crystals.	No action ?	No action.	Qu.	Qu. Indirect ?
Precipitation from nitrous solution.	No action on the metal. Sparing solution of pre- cip. Separates it from nitr. acid. White powder nearly in- sol.	Gray metallic precipitate from acid solution.	No action.	Qu.	Qu. Indirect ?
Precipitation from nitrous solution.	No action on the metal. Unites with calx. White comp. sparingly sol. Separates from vitr. and nitr. solutions.	Orange coloured precipi- tate from acid solution.	No action. Separates a white powder from the acetous solu- tion.	Qu.	Qu. Indirect ?
Qu.	Solution and calcination. Crystals. Calx easily soluble.	Qu.	No action.	Qu.	Qu. Indirect ?
Solution ?	Solution of metal and of calces. Light blue powder, in sol. but with excess of acid. Separates from vitr. nitr. and mar. solution.	Brown precipitate from acid solution.	No action.	Qu.	Qu. Indirect ?
Qu.	No solution of the metal. Calces and precipitates are soluble. Crystals nearly insol. Separates it from nitr. acet. and mar. acids. 55 lead. 45 acid ?	White precipitate from acetous solution.	No action. Separates a white powder from the acetous solu- tion.	Qu.	Qu. Indirect ?
Solution ?	Solution with efferves. Crystals efflores. fol. 45 iron. 55 acid, partly in excess.	Black precipitate from vitriolic solution. Ink ?	Solution.	Brown solution. No crystals.	Qu. Indirect ?



Component Parts.	Empyreumatic acid of wood.	Empyreumatic Acid of Sugar, &c.	Acid of Camphor.	Acid of milk.	Acid of sugar of milk.
Calx of Gold.	Qu.	Solution of gold leaf, and also of the calx.	Qu.	No action.	No action?
Calx of Platina.	Qu.	Qu.	Qu.	Qu.	Qu.
Calx of Silver.	Qu.	No action.	Qu.	No action.	No action? Precipitate from nitrous solution.
Calx of Mercury.	Qu.	No action.	Qu.	No action.	No action? Precipitate from nitrous solution.
Calx of Tin.	Qu.	Solution and corrosion.	Qu.	No action.	No action. Indirect?
Calx of Copper.	Qu.	Solution. No crystals.	Qu.	Slow solution. No crystals.	No action. Indirect?
Calx of Lead.	Qu.	Calcination of the metal. Solution of minium. Astringent crystals.	Qu.	Solution sparing?	No action? Precipitate from nitrous solution.
Calx of Iron.	Qu.	Blood-red solution. Green crystals.	Qu.	Solution. No crystals.	No action. Indirect?

Acid of Ants.	Prussian acid.	Acid of fat.	Acid of the Stone of the bladder.	Acid of Silk-worms.	Metallic acids.
No action.	Precipitate from acid solution by double affinity.	Solution of the metal, with the assistance of one-third nitrous acid, or by abstraction from manganese. Calces or precip. dissolved. Crystals. Separates it from aq. reg. Habitudes as with gold.	Qu.	Qu.	No arsenical comb. White molybdenic precipitate from acid.
No action.	No combination direct. Nor indirect?		Qu.	Qu.	Arsenical comb. by double affinity. Yellow.
No action on the metal. Solution of the calces. Crystals.	Precip. by double affinity from nitrous solution. Brick-coloured powder.	Sparing solution. Precip. difficultly dissolved. Separates it from nitrous acid.	Indirect?	Qu.	Arsenical solution. precipitate by single and also by double affinity. Molybdenic precipitate from nitrous acid.
No action on the metal. Solution of the calces. Crystals. Reduces the calces??	Precip. by double affinity from nitrous solution. White and yellow?	Combination by repeated abstraction. Precip. soluble. White precip. from solut. of cor. sublim. Characteristic of this acid.	Indirect?	Qu.	Arsenical combination direct, by distill. Insoluble in water. Indirect combinations. Molybdenic precipitate from nitrous solution.
No action on the metal. Nor the calces?	Precip. by double affinity from nitrous solution. Dark green or blue powder.	Combination or corrosion and partial solution. Deliques. salt.	Indirect?	Qu.	Gelatinous arsenical solution. precipitate by double affinity. Brown molybdenic precipitate from mar. acid.
No action on the metal. Solution of the calces. Crystals.	Precip. by double affinity from nitrous solution. Dark-red powder.	Solution by heat. Deliques. crystals.	Indirect?	Qu.	Green arsenical solution. Blue molybdenic precipitate.
No action on the metal. Solution of the calces. Crystals.	Precip. by double affinity from nitrous solution. Greenish yellow powder. Becomes white.	Corrosion of the metal. Solution of calces. Sweetish; soluble crystals?	Indirect?	Qu.	Arsenical combin. by distill. Molybdenic precipitate from nitrous solution.
Solution of the metal and of the calces. Crystals.	Precip. by double affinity from vitriolic or marine solution. Deep blue, or Prussian blue.	Solution. Deliques. crystals.	Indirect?	Qu.	Gelatinous solution by access of air. Brown molybdenic precipitate from mar. acid.



Component Parts.	Vegetable alkali.	Mineral alkali.	Volatile alkali.	Vitriolic acid.	Sulphureous acid.
Calx of Zinc.	In the dry way ? In the humid way sparing solution. Indirect ?	As the vegetable alkali.	Sparing solution.	Solution in diluted acid. White crystals. Soluble in 2 p. water. 25 metal ? 32 acid ? 33 water ?	Qu.
Calx of Manganese.	In the dry way solution of the calx. Blue or green colour. Pellucid when less calcined in the mixture.	As the veg. alk. ?	Qu.	Solution of the metal. Most effectual with dilution. Crystals. If too much calcined insol. unless inflam. matter be added.	Solution as with vitriolic acid and inflam. matter.
Calx of Nickel.	Sparing solution, yellow.	As the vegetable alkali ?	Blue solution.	Solution of the calx. Green crystals.	Qu.
Calx of Bismuth.	Qu.	Qu.	Qu.	Calcination and solution.	Qu.
Calx of Antimony.	Dry combin. ? ?	Dry combin. ? ?	Qu.	Calcination and solution. Not crystalliz.	Qu.
Calx of Cobalt.	Dry combin. ? In the humid way sparing solut. ?  Solution of precipitate from nitr. acid.	As the veg. alk. ?	Qu.	Difficult solution. Crystals.	Qu.
Calx of Arsenic.	Combin. with the calx. Gelatinous, deliques.	Combin. with the calx. Crystal.	Qu.	Solution by heat. But total separation of calx by cooling.	Qu.
Calx of Molybdena.	Combination when acidified. Small crystals.	As the vegetable alkali ?	Combination ?	Solution of the acid. Becomes thick and blue by cooling.	Qu.
Calx of Wolfram.	Combination with the calx.	Combination with the calx.	Combination with the calx. Crystals. Decompos. by heat.	No action.	No action ?

Nitrous acid.	Marine acid.	Aerated marine acid.	Nitro-muriatic acid.	Phosphoric acid.	Aerial acid or fixed air.
Rapid combination with diluted acid. Crystals. Deliques.	Rapid solution. No crystals.	Qu.	Qu.	Fetid gum-like solution. Not crystalliz. but by evap. and fusion forms transparent glass.	Solution. Indirect comb. or precip. Dull white.
Solution with the leading phenomena as in vitr. acid. No crystals ? ?	Solution of the metal. Also the calx with escape of aerated marine acid. Crystals ; Deliques ?	Solution as of the calx in marine acid.	Solution.	Slow solution of the calx. Indirect comb. by microsc. salt to an acid solution.	Solution. White pellicle.
Solution. Green deliques. crystals.	Solution. Green deliques. crystals.	Solution ?	Solution ?	Very sparing action.	Indirect combin. by double affinity. Greenish.
Very rapid solution. Crystals, effloresc. Water abstracts the acid and throws down a white calx ; Magistery of bismuth.	Solution by repeated abstraction. Deliquescent crystals, or butter of bismuth.	Qu.	Qu.	Solution.	Indirect. White precip.
Strong action. Calcination and solution. Deliques. crystals.	Weak action. Solution. Deliques. crystals.	As the nitro-muriatic ?	Rapid solution. Deliques. crystals.	Qu.	Indirect ?
Solution. Deliques. crystals.	Solution of the metal and of the calx. Reddish brown, but green while hot. Deliques. crystals.	As the nitro-muriatic ?	Solution. Green while heated. Sympathetic ink.	Solution of calx.	Indirect combin. or precip. Greenish pale red.
Solution ; calcination, acidification, according to quantities, circumstances and management.	Solution of regulus ? ?	Acidification ?	Solution of calx.	Solution of calx.	Indirect combin. or precip. ? ?
Acidifies the metal, but does not dissolve the acid.	Solution of the acid.	Qu.	Qu.	Qu.	Qu.
No action ? Triple compound with excess of acid, and a portion of alkali ; Acid of tungsten so called.	Insoluble.	Qu.	Qu.	Qu.	Qu.



Component Parts.	Acid of Borax.	Acid of Fluor.	Acid of Amber.	Acetous Acid.	Acid of Tartar.
Calx of Zinc.	Light green slag by fusion with the calx. Turbid solution. crystalliz. ?	Strong action on the metal and its calces. Crystals ?	Ready solution of the metal. Solution of precip. Crystalliz.	Solution. Magma. Crystalliz. after dilution. By heat slight fulmination; blue flame; decomposition of acid.	Ready solution. Salt of sparing solubility.
Calx of Manganese.	Qu.	Salt of difficult solution which impedes the progress of the acid.  Indirect combination by fluorated vol. alk. and acid solut.	Qu.	Very difficult solution. Deliques. salt.	Solution. If heated decompos. of part of the acid with effervescence. Crystal.
Calx of Nickel.	Qu.	Gelatinous solution of calx. Green crystals.	Combination and partial decomposition of the acid.	Solution. Green crystals.	Qu.
Calx of Bismuth.	White transparent glass by fusion of the humid compound. No direct humid action, but borax gives a white powder from the sol. in mixt. of vit. and marine acids.	No action on the metal. Solution of calx. No crystals, but a powder separated.	Solution of the metal with heat. Solution of precip. Crystalliz.	Bitter acid solution. Not crystalliz.	Crystalline precipitate from nitrous solution.
Calx of Antimony.	Qu. dry way.  Precip. by borax from the reguline solution is soluble by this acid.	No action.	Little action on the metal. Solution of precip.	Very sparing solution.	No action on the metal. Solution of calces.
Calx of Cobalt.	Imperfect combin. by fusion.  Precip. from acid by borax.	No action on the metal. Solution of calx.	Qu.	Pale rose-coloured solution. Crystalliz. ?	Qu.
Calx of Arsenic.	Combination with the calx either in the humid or dry way. Soluble in water. Crystallizable.	Solution of calx. Small crystals.	Qu.	Regulus not sol. Calx soluble with heat. Decomposition or change in the acid ?	Qu.
Calx of Molybdena.	Qu.	Qu.	Qu.	No action ?	Qu.
Calx of Wolfram.	Qu.	Qu.	Qu.	Change of colour in the calx to blue. No solution ?	Qu.

Emphyreumatic Acid of Tartar.	Acid of Sugar.	Acid of Galls.	Acid of Lemons.	Acid of Apples.	Acid of Benzoic.
Qu.	Combination with violent effervescence. White powder, infol. in water unless acid in excess. 3 metal. 1 acid. Precip. from vitr. nitr. and mar. acid.	No action on the metal? No precip. from solution in an acid.	Solution. Fine crystals.	Solution. Fine crystals.	Qu.
Qu.	Solution. White pulverulent precip. unless acid in excess.  Precipitates crystals from vitr. nitr. or mar. solutions.	No action, or precipitate from acid.	Solution with partial decomposition of the acid if heated.	Qu. Decomposition with calx?	Qu.
Qu.	Greenish combination. Nearly insoluble. 1 metal. 2 acid. Precipitates from vitr. nitr. and mar. solutions.	Qu.	Qu.	Qu.	Qu.
Qu.	Corrosion of the metal; Solution of the calx. White powdery salt, nearly insoluble. 1 metal. 1 acid. Precip. crystals from nitr. solution.	Orange yellow precipitate from an acid solution.	Qu.	Qu.	Qu.
Qu.	Slow solution with excess of acid. Crystalline grains scarce soluble. Precip. from acetous and vitr. solutions.	Qu.	Qu.	Qu.	Qu.
Qu.	Solution. Rose-coloured powder if neutral, scarce soluble. Crystals with much excess of acid; easily sol. Precipitate of the rose- coloured powder from every known acid.	No action, nor precip. from acid solution.	Qu.	Qu.	Qu.
Qu.	Solution of white calx. Crystals with excess of acid; soluble in water; and in ar. sp. ?? Sublimed by gentle heat, decomposed by stronger.	No action nor precip.	Qu.	Qu.	Qu.
Qu.	Qu.	Indirect combination or precipitate from the marine solution. Dark brown. This was with the infusion. With the acid no precip.	Qu.	Qu.	Qu.
Qu.	Qu.	Qu.	Qu.	Qu.	Qu.



Component parts.	Empyreumatic acid of wood.	Empyreumatic acid of sugar.	Acid of camphor.	Acid of milk.	Acid of sugar of milk.
Calx of zinc.	Solution. Crystalliz. ?	Metal partly dissolved; Greenish; partly cal- cined; greyish.	Solution.	Solution. Crystals.	Precip. by double affin. Insoluble.
Calx of manganese.	Solution, with partial de- compos. of acid ? ?	Qu.	Qu. solution.	Qu.	Precip. by double affin. Insoluble.
Calx of nickel.	Qu.	Qu.	Qu.	Qu.	Precip. by double affin. Insoluble.
Calx of bismuth.	Qu.	Qu.	Solution.	No action.	Precip. by double affin. Insoluble.
Calx of antimony.	Qu.	Greenish solution.	Qu.	No action.	Precip. by double affin. Insoluble.
Calx of cobalt.	Qu.	Qu.	Solution.	No action.	Precip. by double affin. Insoluble.
Calx of arsenic.	Qu.	Qu.	Solution. Of the regulus?	Qu.	Precip. by double affin. Insoluble.
Calx of molybdena.	Qu.	Qu.	Qu.	Qu.	Precip. by double affin. Insoluble.
Calx of wolfram.	Qu.	Qu.	Qu.	Qu.	Precip. by double affin. Insoluble.

Acid of ants.	Prussian acid.	Acid of fat.	Acid of the stone of the bladder.	Acid of silk-worms.	Metallic acids.
Considerable action and solution. Crystals.	Indirect combination or precipitate from nitrous acid. Reddish yellow, becomes whitish.	Copious solution.	Indirect combin. ?	Qu.	Arsenical solution of the metal. Insoluble combination defends the residue. In the dry way combination and explosion. Indirect combination humid.
Qu.	Indirect combin. or precipitate. Dirty blueish gray.	Copious solution.	Indirect combin. ?	Qu.	Arsenical solution. Crystals. Indirect arsenical combin. by double affinity.
Green solution of the calx. Deep green crystals; hemispherical radiated; scarcely soluble in water unless an acid be present.	Indirect combination or precipitate from nitrous acid. Dirty reddish yellow.	No direct action. Solution of precip.	Indirect combin. ?	Qu.	Very slight direct action by arsenical acid. Indirect combination by double affinity.
Solution of the calx. Crystals.	Indirect combination or precipitate from nitrous acid. Reddish yellow.	No action on metal. Solution of precip.	Indirect combin. ?	Qu.	Arsenical solution precipitable by water. In the dry way calcination: But not solution. Indirect combin. humid.
Solution of the calx?	Indirect combination or precipitate. Blue; easily dissolved by excess. Green.	Solution by heat. Permanent crystals.	Indirect combin. ?	Qu.	Arsenical combination. Calcination and solution precipitable by water. In the dry way combination with inflam.
Solution of the calx.	Indirect combination or precipitate from nitrous acid. Blue; more gray than that of iron.	No action on metal. Precip. dissolved.	Indirect combin. ?	Qu.	Sparing arsenical solution. Rose-colour. Indirect combinations.
Solution of the calx.	Indirect combination or precipitate from marine acid or aqua regia. Green and yellow mixt.	Copious solution of the white calx. Crystals.	Indirect combin. ?	Qu.	
Qu.	Indirect combination or precipitate from the marine solution. Brown.	No action.	Indirect combin. ?	Qu.	Qu.
Qu.	No precipitate from the nitrous or acetous solution.	Qu.	Indirect combin. ?	Qu.	Qu.



TABLE III. *Compounds of certain Products of Organization.*

Component Parts.	Fixed Alkalies.	Volatile Alkali.	Acids.	Ardent Spirit.	Sulphur and Phosphorus.
Gum. Sol. in water; afford oil when distilled with alkali. Turns sour and putrefies. Destroyed by fire; but scarcely inflamm.	Coagulate the aqueous solution. No combin.?	As fixed alkali?	With nitrous acid by ab- straction affords acid of sugar.	Insoluble. Precipitable from water. Unchanged?	Qu.
Fat oils. Insol. in water. Do not rise by the water bath. Inflam. when boiling. Under these class wax? Spermaceti? Caout- chouc??	Soap. Diffusible in water and separable on the filire? Soluble in ar. sp. Heavier than oil and dif- ficultly burned.	Imperfect soap.	Decomposition of both and partial combina- tion.	Insoluble.	Solution. Balsam of sulphur.
Volatile oils. Insol. in water. Rise in distill. on the water bath. Inflammable. Under these aroma or sp. rector?? camphor??	Imperfect soap.	Imperfect soap.	Imperfect combin. if weak. Combustion with strong nitrous acid.	Solution.	Solution.
Resins. Insol. in water. Decomposed in distill. Very combustible. Mostly soluble in fat oil. Under these lac?	Soap.	Soap?	More or less of combus- tion, or an equivalent process.	Solution.	Combination?
Starch. Not soluble in cold water, but combinable with heat. More inflammable than gum.	Qu.	Qu.	With nitrous acid ab- stracted. Acid of sugar.	Qu.	Qu.
Sugar. Very soluble in water, crystallizes by cooling Combustible.	Solution??	Solution.	Solution. With nitrous acid abstr. Acid of sugar.	Solution In 12 parts heated. Very sparingly cold.	Qu.
Vegetable gluten. Absorbs water and is then insoluble in it. Small masses dry and be- come brittle, larger putrefy. Burns like animal mat- ters.	Solution by heat precipi- table by acids.	As fixed alkali?	Solution with decompo- sition. By abstraction of nitrous acid. Acid of sugar.	No Action? Extracts the water?	Qu.
Animal mucilage or glue. Soluble in water, fluid when hot, thick and adhesive when cold, may be boiled without alteration.	Solution. With decompos.?	Solution? With decompos.	Solution. With decompos.	No action? Precipitates from water?	Qu.
Serum. Soluble or diffusible in cold water. Coagulates and becomes insoluble by heat of 167° Fahrenheit. Said not to differ from curd and white of egg.	Solution and greater flu- idity. Qu. decomposition?	Solution.	Coagulation, Not soluble in water.	Coagulation. Soluble in water.	Qu.

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TABLE of the Correspondence of the Thermometers of Fabrenheit, Reaumur, and Celsius.

Fahr.	Reaum.	Celsi.	Fahr.	Reaum.	Celsi.	Fahr.	Reaum.	Celsi.	Fahr.	Reaum.	Celsi.
212	80.0	100	159	56.4	70.5	106	32.8	41.1	53	9.3	11.6
211	79.5	99.4	158	56	70	105	32.4	40.5	52	8.8	11.1
210	79.1	98.8	157	55.5	69.4	104	32	40	51	8.4	10.5
209	78.6	98.3	156	55.1	68.8	103	31.5	39.4	50	8	10
208	78.2	97.7	155	54.6	68.3	102	31.6	38.8	49	7.5	9.4
207	77.7	97.2	154	54.2	67.7	101	30.6	38.3	48	7.1	8.8
206	77.3	96.6	153	53.7	67.2	100	30.2	37.7	47	6.6	8.3
205	76.8	96.1	152	53.3	66.6	99	29.7	37.2	46	6.2	7.7
204	76.4	95.5	151	52.8	66.1	98	29.3	36.6	45	5.7	7.2
203	76	95	150	52.4	65.5	97	28.8	36.1	44	5.3	6.6
202	75.5	94.4	149	52	65	96	28.4	35.5	43	4.8	6.1
201	75.1	93.8	148	51.5	64.4	95	28	35	42	4.4	5.5
200	74.6	93.3	147	51.1	63.8	94	27.5	34.4	41	4	5
199	74.2	92.7	146	50.6	63.3	93	27.1	33.8	40	3.5	4.4
198	73.7	92.2	145	50.2	62.7	92	26.6	33.3	39	3.1	3.8
197	73.3	91.6	144	49.7	62.2	91	26.2	32.7	38	2.6	3.3
196	72.8	91.1	143	49.3	61.6	90	25.7	32.2	37	2	2.7
195	72.4	90.5	142	48.8	61.1	89	25.3	31.6	36	1.7	2.2
194	72	90	141	48.4	60.5	88	24.8	31.1	35	1.3	1.6
193	71.5	89.4	140	48	60	87	24.4	30.5	34	0.8	1.1
192	71.1	88.8	139	47.5	59.4	86	24	30	33	0.4	0.5
191	70.6	88.3	138	47.1	58.8	85	23.5	29.4	32	0	0
190	70.2	87.7	137	46.6	58.3	84	23.1	28.8	31	0.4	0.5
189	69.7	87.2	136	46.2	57.7	83	22.6	28.3	30	0.8	1.1
188	69.3	86.6	135	45.7	57.2	82	22.2	27.7	29	1.3	1.6
187	68.8	86.1	134	45.3	56.6	81	21.7	27.2	28	1.7	2.2
186	68.4	85.5	133	44.8	56.1	80	21.3	26.6	27	2.2	2.7
185	68	85	132	44.4	55.5	79	20.8	26.1	26	2.6	3.3
184	67.5	84.4	131	44	55	78	20.4	25.5	25	3.1	3.8
183	67.1	83.8	130	43.5	54.4	77	20	25	24	3.5	4.4
182	66.6	83.3	129	43.1	53.8	76	19.5	24.4	23	4	5
181	66.2	82.7	128	42.6	53.3	75	19.1	23.8	22	4.4	5.5
180	65.7	82.2	127	42.2	52.7	74	18.6	23.3	21	4.8	6.1
179	65.3	81.6	126	41.7	52.2	73	18.2	22.7	20	5.3	6.6
178	64.8	81.1	125	41.3	51.6	72	17.7	22.2	19	5.7	7.2
177	64.4	80.5	124	40.8	51.1	71	17.3	21.6	18	6.2	7.7
176	64	80	123	40.4	50.5	70	16.8	21.1	17	6.6	8.3
175	63.5	79.4	122	40	50	69	16.4	20.5	16	7.1	8.8
174	63.1	78.8	121	39.5	49.4	68	16	20	15	7.5	9.4
173	62.6	78.3	120	39.1	48.8	67	15.5	19.4	14	8	10
172	62.2	77.7	119	38.6	48.3	66	15.1	18.8	13	8.4	10.5
171	61.7	77.2	118	38.2	47.7	65	14.6	18.3	12	8.8	11.1
170	61.3	76.6	117	37.7	47.2	64	14.2	17.7	11	9.3	11.6
169	60.8	76.1	116	37.3	46.6	63	13.7	17.2	10	9.7	12.2
168	60.4	75.5	115	36.8	46.1	62	13.3	16.6	9	10.2	12.7
167	60	75	114	36.4	45.5	61	12.8	16.1	8	10.6	13.3
166	59.5	74.4	113	36	45	60	12.4	15.5	7	11.1	13.8
165	59.1	73.8	112	35.5	44.4	59	12	15	6	11.5	14.4
164	58.6	73.3	111	35.1	43.8	58	11.5	14.4	5	12	15
163	58.2	72.7	110	34.6	43.3	57	11.1	13.8	4	12.4	15.5
162	57.7	72.2	109	34.2	42.7	56	10.6	13.3	3	12.8	16.1
161	57.3	71.6	108	33.7	42.2	55	10.2	12.7	2	13.3	16.6
160	56.8	71.1	107	33.3	41.6	54	9.7	12.2	1	13.7	17.2



ADDITIONAL

## A D D I T I O N S.

*Acid of Tartar, Empyreumatic.*

**ACID OF TARTAR, EMPYREUMATIC.** By the distillation of cream of tartar, an aqueous acid is afforded, which has been called spirit of tartar. It has a very pungent smell, and cannot easily be rectified a second time on account of the sudden production of elastic fluid, which bursts the vessels. Its combinations have been little inquired into. It forms with the fixed alkalis crystallizable salts, which are soluble in cold water.

*Charcoal.*

**CHARCOAL.** I. The first analytical experiments in proof of the decomposition of fixed air were made by Mr. Tennant, and are inserted in the eighty-first volume of the Philosophical Transactions. He applied phosphorus to red hot marble, and obtained charcoal, phosphoric acid, and lime. Dr. Pearson, in Part II. of the Transactions for 1792, makes some judicious observations on the action of the affinities in this experiment, which led several chemists to suspect, that the small quantity of charcoal might have pre-existed in the phosphorus, which is in fact obtained by distillation with that substance. And for this reason he made experiments, by heating phosphorus in contact with other substances. The mild fossil alkali, cleared of its water of crystallization by previous heating, was in the quantity of eight hundred grains pressed down upon two hundred grains of transparent phosphorus, in a thick white glass tube, about one inch in diameter, and three feet and a half long, coated at the part containing the alkali. Heat sufficient to soften the tube was then applied to the coated part, and in this state the end containing the phosphorus was gradually drawn over the fire and kept ignited for twenty minutes. By the sublimation of the phosphorus, and its contact with the ignited salt, part of the carbonic acid, or fixed air, was decomposed and deprived of its vital air, leaving charcoal, its other component part, behind. Of this, by solution and filtration, he obtained 32.4 grains, which he examined by combustion, by deflagration with nitre, by reduction of lead, and by the distillation of phosphorus from its acid. It was indubitably charcoal. Very satisfactory examinations were also made by the Doctor of every one of the other products and residues, which shewed that the carbonic acid had been truly decomposed.

Similar experiments were made by the application of phosphorus to mild vegetable alkali, and also to the calcareous, ponderous, magnesian, and argillaceous earths. The Doctor does not give the detail of the results, or indeed speak with precision of the quantities of the products; but he thinks the conclusion may be admitted, that the carbonic acid, combined with any of these substances, will be decomposed at a due degree of heat. He could not decompose it with the volatile alkali; neither in fact could this be expected, from the known circumstance, that charcoal itself separates the phosphoric acid from that body.



# ADDITIONS

( 1098 )

# CHARCOAL.

Phosphorus applied in Dr. Pearson's method to quick-lime afforded no charcoal, but an hepatic compound, explosive by a gentle heat, which emitted bubbles of phosphoric air when thrown into cold water, and these exploded as usual when they arrived in contact with the air of the atmosphere. Neither did caustic alkali afford charcoal, except a minute quantity arising from the carbonic acid, of which that alkali cannot be totally cleared. The vitriolic and marine combinations with the fixed alkalis did not afford any charcoal.

II. The absorption of elastic fluids, slightly mentioned under the Article CHARCOAL, is a singular fact very difficult to be accounted for. The fluids seem to be merely condensed, and not combined. Does the charcoal absorb that heat which before maintained the elastic state?

This discovery, first made by the Abbé Fontana, was afterwards pursued and extended by various other eminent chemists. The Count Morozzo, in the Journal de Physique for April 1783, relates a series of experiments made to ascertain the quantities of air thus absorbed by equal volumes of charcoal passed into a tube containing the elastic fluid over mercury. The ignited coal was plunged into the mercury, and arose into the tube, of which the length above the mercury was 12 inches. The absorptions are expressed in inches and lines.

	In.	L.
Of atmospheric air absorbed	3	6
Fixed	11	0
Alkaline	8	8
Nitrous	6	10
Inflammable	2	1
Vital from red precipitate	2	2
from nitre	1	1
from water	2	1
Atmospheric air vitiated		
By the combustion of a taper	3	8
of sulphur	3	9
By the mutual action of sulphur and iron filings } moistened	3	6
By the respiration of small animals	3	4

III. Mr. Lowitz and after him other chemists have observed a remarkable property in charcoal, by which it purifies various mucilaginous saline and other bodies. This is amply shewn under the article VINEGAR. The following general paper is extracted, with very little abridgment, from the second volume of the English Translation of Crell's Journal.

1. Common vinegar when boiled in a matrass with charcoal powder becomes perfectly limpid. 2. Terra foliata tartari could never be rendered white with this colourless vinegar; but, to effect this, vinegar that has been previously distilled must be used. 3. When honey diluted with water is boiled with charcoal powder, a very unpleasant smell is produced. 4. When the necessary quantity of charcoal powder is added to hydromel, the liquor runs through the filter as clear as water. 5. The residuous charcoal powder, when lixiviated with a large quantity of water, renders the water of a semi-pellucid black colour. 6. If this black water be evaporated, the black matter will be deposited on the sides of the vessel in the form of a very soft and unctuous powder. 7. An ounce of gum arabic boiled with 30-lbs. of charcoal powder and sufficient water, was entirely lost in the process, either by decomposition or absorption. 8. Fluids which contain

contain either vegetable mucilage or animal gluten, will not run clear through the filter without the addition of charcoal powder. 9. Beer, milk, and lemon-juice, when diluted with a prodigious quantity of water, and mixed with a sufficient quantity of charcoal powder, remain of a turbid black colour. 10. Hence it follows, that the charcoal powder may be advantageously used in the separation of oily, gummy, mucous or gelatinous matter. 11. The charcoal powder which remained after the purification of a mother-ley of phlogisticated alkali rendered the water with which it was lixiviated of a beautiful bright green colour. 12. Charcoal powder over which a very empyreumatic distilled vinegar that had been concentrated by freezing had been abstracted till the charcoal was become dry, displayed upon its surface all the colours of a peacock's tail. 13. Charcoal powder over which some common vinegar that had been frozen had been distilled with a strong heat, when mixed with water, ran over the sides of the glass jar in which the mixture was made, with a thick froth. 14. Glass vessels and other utensils may be purified from long retained smells, by rinsing them out well with charcoal powder. 15. Honey perfectly pure may be obtained from the scum of clarified honey, by diluting it with water, and adding to it while upon the fire a proper quantity of charcoal powder. 16. Charcoal has no effect upon the bitter taste of salt water. 17. Salt of hartshorn is rendered uncommonly white, when triturated with an equal quantity of charcoal powder, and put into a retort for distillation so as to fill it half way up. 18. A large quantity of acid of tartar treated with charcoal powder, was brought to the point of crystallization in seventeen hours, and was afterwards found to be perfectly limpid and free from empyreuma. 19. Common ardent spirit purified by charcoal without distillation, is always found to be of a blackish turbid appearance, when too little of the powder is added. But this black matter may be instantly separated from the spirit by the addition of a sufficient quantity of dry salt of tartar, which dephlegmates the spirit. 20. When three pounds of oil of hartshorn were mixed with two pounds of charcoal powder, and put into a cucurbit, a little dark brown oil ascended at the last part of the process. 21. When no charcoal was added, the operation was finished with a gentle heat in twelve hours, and the obtained oil was not inferior to the former either in quantity or quality. 22. The extraordinary property which charcoal possesses of attracting the strongest part of vinegar, and not giving it out in distillation, has been already noticed in the article VINEGAR. 23. When a glass funnel was filled with charcoal coarsely pounded and riddled, and a few pounds of the black concentrated liquor which remains after the distillation of Hoffman's anodyne drops, poured upon it, this black acid in the course of two months was rendered perfectly colourless. 24. By rubbing and washing out the mouth and teeth thoroughly with fine charcoal powder, the smell of bad breath may be remedied. 25. Putrid stinking water was immediately deprived of its offensive smell by means of charcoal powder, and rendered transparent. 26. When the acid of ants was mixed with charcoal powder, it was found to be of a dark turbid appearance, and did not begin to come clear till six months had elapsed. 27. On saturating six pounds of the same acid of ants with purified pot-ash, it was constantly of a dark turbid appearance, and yet it ran through four folds of blotting paper as readily as pure water. 28. On distilling the acid of ants with a great quantity of charcoal powder, that which came over towards the end of the distillation was of a brown colour and empyreumatic. The residuum contained in the retort was strongly caked together, and imparted a very deep brown colour to water. 29. The bad smell of putrid



urine is taken away by mixing charcoal powder with it while boiling; and the residuum when lixiviated with water, affords a liquor as clear as water, and which when evaporated to the point of crystallization was fluid enough to allow the salts which it contained to shoot into beautiful white crystals of cubical and other forms. 30. Charcoal powder deprives pure alkali, when saturated with the colouring matter of Prussian blue, of its yellow colour. 31. Charcoal without the assistance of heat rendered a watery solution of liver of sulphur colourless and inodorous. On adding oil of vitriol to the solution, precipitation and the smell of hepatic air ensued after some hours had elapsed. 32. A solution of liver of sulphur deprived of its colour by charcoal when evaporated to dryness yielded a perfectly white saline residuum, which being laid upon burning charcoal entered into a red fusion, without shewing any mark of sulphur: and a solution of the same substance evaporated to dryness without charcoal, gave a blackish saline residuum, which upon being laid on heated charcoal broke out into a blue flame, and emitted a strong sulphureous smell. 33. When a small quantity of a balsam of sulphur prepared with some essential oil, is dissolved in highly rectified spirit of wine, and afterwards mixed with charcoal powder, the smell of the essential oil alone remains. 34. Neither the watery nor spirituous solution of soap is changed by treatment with charcoal. 35. Camphor and its odour are not in the least altered by charcoal; yet when this last is added to a solution of unrefined camphor in spirit of wine, it deprives the same of its yellow colour. 36. When a sufficient quantity of charcoal is added to a saturated solution of camphor in highly rectified spirit of wine, the camphor will shoot into plumous crystals, which, accordingly as the weather is warmer or colder, will alternately disappear and re-appear. 37. On strongly boiling cream of tartar and charcoal powder with water, the whole of the cream of tartar became crystallized in regular, large, flat, transparent crystals, entirely different in their figure from the common crystals of this salt. 38. In the above-mentioned experiment tartarised calcareous salt was also crystallized among the charcoal powder, in the form of roundish transparent polygons, of a remarkably beautiful golden colour. 39. From four ounces of a very brown oily salt of amber well triturated with two pounds of fine charcoal powder, and put into a large retort, not quite a dram of salt of amber was collected, that was as white as snow and almost inodorous. This salt could not be converted into acid of sugar. 40. Flowers of benzoin obtained by sublimation are rendered uncommonly white and shining when treated with charcoal powder. Under this purifying treatment the oil of benzoin comes over as clear and colourless as water; but by length of time becomes yellow again. 41. Acid of apples is entirely destroyed or decomposed by digestion with charcoal, so that nothing remains but mere water, with a very little extractive matter of the nature of a neutral salt. 42. Honey when boiled with charcoal after the separation of the charcoal powder recovers the brown colour which it lost at first. 43. By trituration with charcoal powder bugs (cimices) were entirely deprived of their bad smell. 44. The strength of spirits distilled from malt is increased by the mere addition of charcoal. 45. This increase of strength was ascertained by comparative experiments of specific gravity; and of dephlegmation as well by salt of tartar as by distillation. It seems to be in some measure doubtful, whether this process might be advantageously substituted instead of those at present in use. Mr. Lowitz thinks it may, and relates various experiments with observations to that effect. He remarks that ardent spirit completely purified by charcoal has a fine smell, exactly resembling  
that

that of peaches. Does this fact bear any relation to the fire damp of coal mines which smells of peach-blossoms, and probably consists of some modification of fixed and inflammable air? 46. Vinegar is not weakened by distillation with charcoal, but too large a quantity appears to decompose it, as is the case with ardent spirit in the like circumstances. 47. The acid of wood obtained by distillation from *lignum vitæ*, or *guaiacum*, when distilled with charcoal was very readily purified from the great quantity of empyreumatic oil which adheres to it: and a true glacial vinegar was obtained by concentrating it to a very high degree. 48. From two ounces of charcoal powder mixed with eight ounces of smoking spirit of nitre, three ounces six grains of smoking acid, of a very beautiful dark green colour were obtained. 49. On pouring eight ounces more of fresh smoking spirit of nitre to the residuous charcoal powder, after it was become cold, a quantity of ignited sparks suddenly appeared in the retort which broke in pieces, whilst the charcoal took fire, but without detonation. 50. The experiment with eight ounces of smoking spirit of nitre and two ounces of charcoal powder was again repeated in the same way as No. 48. When the distillation was over, the residuous charcoal powder was somewhat shining in its upper part, but not much caked or agglutinated. In order to see whether it had suffered any alteration from this first operation, Mr. Lowitz subjected very small quantities of it to the following trials:

(a) When thrown upon burning charcoal it did not produce the slightest detonation, nor did it give out any smell.

(b) Applied to the tongue, it did not give out any saline taste.

(c) From a diluted brown lixivium of acid of tartar it extracted all the colour in the course of five minutes without the assistance of heat; whence it appears that it had not yet lost its dephlogisticating power.

(d) The affusion of smoking spirit of nitre upon it was followed by an extrication of heat, but not by inflammation. 51. This charcoal powder, which did not yet seem to have undergone the least alteration, Mr. Lowitz put again into the retort; he then mixed together the acid liquors (whose specific gravity was 1,325, and whose concentration amounted to twenty-nine degrees) obtained in the distillations No. 50 and No. 48, and poured them upon the charcoal. After this second distillation to dryness, the specific gravity of the obtained liquor was found to be 1,317, and its concentration twenty degrees. 52. After the third distillation, the specific gravity amounted only to 1,417, and the concentration to only fourteen degrees. The charcoal powder did not even yet shew the least signs of solubility. 53. As the distilled liquor was now become very weak, Mr. Lowitz employed in the fourth distillation nine ounces of common nitrous acid, the specific gravity of which was 1,258, and its concentration equal to twenty-four degrees. At the end of the operation he found the specific gravity of the distilled liquor to be 1,226. The residuous charcoal powder was now become very strongly caked and full of cracks. 54. After the fifth distillation he did not find any difference in the specific gravity of the acid. A saline sublimate was contained in the neck of the retort. 55. After the sixth distillation, the acid whose specific gravity was still 1,222 appeared of a yellow colour. The residuum had now a shining black appearance, like pitch; on pouring upon it some of the distilled liquor, a reddish-brown solution was obtained. 56. After the seventh distillation the acid became still yellower, and its specific gravity was now reduced to 1,218. The residuum was now for the most part soluble in water. 57. Charcoal thus reduced to the form of an extract is as  
soluble



soluble in highly rectified spirit of wine as it is in water. 58. A sufficiently diluted solution of this substance in water is entirely deprived of its colour and bitter taste by fresh charcoal powder. 59. The watery solution of the extract of charcoal when thoroughly evaporated in a sand bath, swells up at the last and becomes perfectly dry; but it soon attracts moisture again by exposure to the air. However, when left to the air for some months, it loses this deliquescent property, and its humidity is gradually dried up. 60. Resin of jalap was rendered extremely pure and colourless by repeated addition of charcoal to the spirituous solution, and subsequent distillation of the menstruum. The loss amounted to half the weight of the resin. 61. Common resin appeared to require so much charcoal for its purification, that Mr. Lowitz abandoned the attempt. 62. Ether which is tainted with a sulphureous smell is not deprived of this smell by charcoal powder. On the other hand, water that has been impregnated as much as possible with such kind of ether, immediately loses this smell when charcoal powder is mixed with it. 63. Charcoal powder has not the least effect upon the strong-smelling substance which is extricated during the distillation of suet and of olive oil. 64. Resins and native balsams dissolved in spirit of wine are deprived of their colour, but not of their peculiar smell, by charcoal powder. 65. The smell of distilled or essential oils is not at all affected by charcoal. 66. All empyreumatic oils, except oleum philosophorum, are entirely deprived of their colour and smell by charcoal. 67. If as much charcoal be added to distilled waters as is sufficient to destroy the smell, the water will always remain turbid; but when a larger quantity of charcoal powder is added, the water becomes perfectly clear and transparent. 68. Charcoal powder not only deprives distilled waters of their smell, but also water impregnated with any sort of empyreumatic oil. 69. A watery infusion of asafœtida and a cold infusion of Virginia snake-root and valerian were entirely deprived of their smell by charcoal powder. 70. Charcoal powder produces no effect when mixed with empyreumatic oils. 71. In like manner the essential oils suffer no loss of smell from the admixture of charcoal powder. 72. The admixture of charcoal with a watery solution of opium deprives it of its peculiar smell. 73. Both white and red wine are rendered colourless by charcoal powder. 74. Charcoal powder produces no change in the common essence of orange-peel. 75. On the other hand it deprives essence of wormwood both of its colour and smell. 76. Both the spirituous and watery tinctures of saffron are in like manner completely deprived of their colour and smell. 77. The spirituous and watery tinctures of red saunders, cochineal, and gum-lac, are also rendered quite colourless. 78. Charcoal powder completely separates all the calcareous particles from lime-water. 79. Water saturated with fixed air is very speedily deprived of the same by charcoal powder. 80. If a little dry charcoal be introduced into a bottle filled with inflammable air, on applying the flame of a candle to the mouth of the bottle, an explosion will be produced, which proves that it must have received some pure air from the charcoal powder. 81. Water impregnated with hepatic air is freed from the same by means of charcoal powder. 82. Onions and garlick, after they have been well bruised or mashed, are quickly deprived of their strong smell by mixture with charcoal powder. 83. Mr. Lowitz found that the coaly residuum after the preparation of dulcified spirit of nitre, and also the coaly matter which remains behind after the distillation of Hoffman's anodyne liquor, are equally as proper for the dephlogisticating processes as charcoal itself. 84. Mr. Lowitz observes, as a remarkable circumstance, that he has successfully employed

employed the thoroughlyedulcorated coaly matter which remains after the distillation of Hoffman's liquor, before it has undergone calcination, to deprive a lixivium of acid of tartar of its yellow colour.

The translator of the papers of Mr. Lowitz, in the English Chemical Journal, adds the following remarks and information in a note which I have not at all abridged.

In the 4th No. of the Chemical Annals for 1791, Mr. Lowitz has pointed out the principal circumstances upon which, after an experience of four years, he has found the success of the dephlogisticating processes with charcoal to depend. To a want of information in these particulars are to be ascribed the failure and disappointment complained of by many chemists who have repeated his experiments. The circumstances so necessary to the success of these operations are reduced to two general heads; viz.

I. The preparation and quality of the charcoal.

II. The mode of employing the charcoal, according to the different nature of the substances to be operated upon. This comprehends whatever relates to

(a) Bringing the substances to be purified, to a state proper for being acted upon by the charcoal.

(b) Adding the charcoal in due proportion.

(c) Adding it at a proper time.

(d) The separation of the charcoal powder from the purified substances; and lastly,

(e) The further treatment of the liquid substances after the separation of the charcoal powder.

I. With regard to the preparation of the charcoal, it is absolutely necessary to deprive it of all its oily matter by making it red-hot throughout its whole substance. Charcoal that has been badly burnt gives out its oily empyreumatic parts, and at the same time a brown colour, even to water, much more to saline leys when boiled therewith. No wonder then, that liquors which are heated with such imperfect charcoal, instead of being made colourless, should even become browner than they would be without such treatment.

For the space of nearly a year after he first discovered the purifying property of charcoal, Mr. Lowitz used to be guided, in the selection of what he wanted for the dephlogisticating processes, merely by outward appearance and lightness. But as in this uncertain mode of proceeding some badly burnt charcoal was usually picked out along with the good, his experiments sometimes proved abortive. He afterwards took the precaution of making the charcoal red-hot throughout; and since that time (viz. for the last three years) he has always accomplished his end.

1. The charcoal must be made quite red-hot in a furnace, and those pieces which cease to give out any smoke must be taken out with tongs, and be laid to cool upon clean bricks. Lest the larger lumps should not have undergone a red heat throughout, and there should still remain a little phlogistic or empyreumatic matter in the heart or middle of them, it will be proper to break them into smaller pieces before they are taken out of the fire; for a single lump of such imperfectly charred coal would counteract or destroy, if not altogether at least in part, the dephlogisticating effect of the rest of the charcoal powder with which it should chance to be mixed.

2. In the next place, great care must be taken that during the cooling the charcoal do not come into contact with any greasy, oily, or other inflammable body; for the smoke which would thus be produced, would be absorbed by the charcoal,



charcoal, and render it unfit for the dephlogisticating processes. For the same reason, the presence of much smoke (in whatever way produced) in the place where the charcoal is prepared, would be highly prejudicial.

3. As soon as the charcoal is become cool, the ashes which adhere to it must be carefully blown off with a pair of bellows; it must then be pounded and passed through a fine hair sieve, and kept for use in clean earthen or glass vessels, closely stopped, in order to keep out the air.

4. Much depends on the fineness of the charcoal powder; for the finer it is, the greater number of acting surfaces are presented to the substances to be operated upon, and consequently a smaller quantity of the powder suffices. By an attention to this circumstance, a good deal of trouble and labour may be saved.

5. The goodness of charcoal powder, thus prepared, may be easily and quickly ascertained by a small trial, in the following manner: Put an ounce of the most empyreumatic and worst kind of ardent spirits into a phial, and add thereto about a couple of drams of the powder; then shake the whole well together. If the charcoal powder is of a proper quality, the ardent spirits will immediately lose their bad smell.

11. Respecting the mode of employing the charcoal, it is to be remarked that a given quantity of charcoal powder attracts only a limited quantity of inflammable matter, after its saturation with which it becomes incapable of any further action.

Hence, when any substance is to be dephlogisticated, it is better to add too much than too little charcoal powder; for in the first case the end will be accomplished, whilst in the latter there will be only a partial dephlogistication, or perhaps none at all.

And yet too great an excess of charcoal must not be employed; for, not to mention that the process is thus rendered much more troublesome, the substances that are operated upon are thereby in danger of being decomposed.

(a) All solid bodies that are to be purified by charcoal (except such as admit of being treated in the dry way, by sublimation) must be previously brought into a fluid state by dissolution in their proper menstrua, from which the undissolved and grosser parts must be afterwards separated by filtration.

Nor is it enough that the substance to be purified be barely dissolved in its proper menstruum; it is further requisite that its solution be duly diluted either with water or spirit of wine, according to the nature of the dissolved substance.

In some cases where an empyreumatic oil, or slimy matter, adheres too strongly to the substance to be purified, it is necessary to boil the fluid along with the charcoal powder even to dryness, and to re-dissolve it afterwards, and this for several successive times, till the purification is completed.

(b) To find out the proper quantity of charcoal powder in operations in the large way, add it little by little to the liquor during the boiling, until it shall be found, by repeatedly taking out small portions and filtering and examining them, that the liquor is become sufficiently pure.

To as much acid of tartar as is obtainable from 30lbs. of crystals of tartar, we are directed to add six ounces of charcoal powder, beginning to add some of it as soon as the liquor is set to evaporate, and continuing the addition till the acid is brought almost to the point of crystallization. In this way 96lbs. of acid of tartar, in the highest degree of purity, and of a perfectly white appearance, were prepared from 300lbs. of cream of tartar.

In the distillation of vinegar, Mr. Lowitz adds 10 or 12lbs. of charcoal powder to 150lbs. of vinegar, and distills to dryness in the open fire. Here the receiver must be frequently changed towards the end of the distillation, since there generally comes over at the last, when the charcoal powder is employed in this proportion, about 6 or 8lbs. of brown empyreumatic vinegar, which, however, may be afterwards purified by a similar distillation with fresh charcoal powder.

A terra foliata tartari, of a snowy whiteness, may be obtained by adding, during the boiling, from four to six ounces of charcoal powder to the product from about 5lbs. of salt of tartar, saturated with vinegar previously distilled with charcoal in the manner before mentioned.

(c) Dry volatile salts, such as flowers of benzoin, salt of amber, salt of hartshorn, &c. should be triturated with an equal quantity of charcoal powder, put into a retort, and covered over to about a hand's breadth with coarse charcoal powder. In the case of acid salts, the proportion of charcoal powder must not be too great; otherwise a considerable loss will be occasioned.

In the purification of ardent spirits, the following is the safest way of proceeding: After the spirit is put into the still, the charcoal must be added little by little, till it is found, by frequently taking out small quantities and diluting them with a little hot water, that all the burnt or empyreumatic smell is gone off; then, and not before, we are to proceed to distillation.

In the case of salts, which by evaporation without charcoal powder constantly become brown and empyreumatic, the charcoal powder must remain mixed therewith, till they are brought quite, or at least very near to the point of crystallization.

(d) The separation of the charcoal powder is easiest and soonest effected by means of a linen strainer. When no more of the liquor will run through of itself, the remainder must be squeezed out as well as possible, and after it has been passed through a fresh filter, and is become quite clear, it may be mixed with the former liquor.

That nothing may be lost, the charcoal powder which remains upon the filter may be lixiviated with water; but there are very few cases in which this last weak lixivium can be added to the former liquors; it must be previously evaporated by itself, and undergo the other subsequent treatment.

A principal rule to be observed is, to strain the liquors that are boiled with charcoal as hot as possible; for they are then in the most fluid state, and consequently the separation of the fine particles of charcoal takes place more readily.

(e) After the separation of the charcoal powder, those lixivia that are liable to be affected by the fire must be evaporated only with the gentlest heat.

In all the experiments with charcoal, in which any comparison is made, in respect to specific gravity, smell, taste, or colour, between the liquors before and after the operation, it is necessary to keep in mind what was added for their due dilution before the treatment with charcoal, and to make allowances accordingly.

If, in the first attempt to deprive any substance of its colour by means of charcoal powder, the operator should not succeed, he must not immediately conclude that charcoal is incapable of producing such an effect upon that substance. The solution might not have been diluted sufficiently. Before any conclusion is drawn, it is necessary that the solution be diluted to an extreme degree (so, however, as to let the colour be still discernible), and that the charcoal powder be



added in the largest possible quantity. Should no alteration then take place, he may safely pronounce that the colour of the substance thus tried, is not affected by charcoal.

Heat is not always required in experiments with charcoal. Cold admixture, assisted by agitation, should be first tried; if this should not succeed, recourse must be had to digestion and boiling.

There are cases in which, notwithstanding the presence of such parts as are actually attracted by charcoal, its use would, in other respects, be improper. In these instances, therefore, before any operations in the large way are attempted, a trial in the small way should be made.

### *Gums.*

**GUMS.** The celebrated Rouelle, in his Course of Chemistry, remarked, that the acid of gummy matters, when exposed to destructive distillation, acts upon their oil, and converts it into coaly matter; whence they afford merely water, acid, and a very small quantity of oil, which is thick, and does not pass through the filter. Mr. Woulfe, in a short paper inserted in the Journal de Physique for May 1788, gives an account of the distillation of gum arabic with one fourth of its weight of the vegetable fixed alkali. This combines with the acid, and accordingly none comes over, but the quantity of oil is considerable, and it is sufficiently attenuated to pass through the filtering paper. Honey, by the same treatment, affords oil copiously.

### *Nitre.*

**NITRE.** The purification of nitre by means of charcoal, forms the subject of a paper by Mr. Gadolin, in the second volume of Crell's Annals (translated) of which the following is an abstract:

1. The difference which takes place in the crystallization between nitre, common and digestive salt, and the deliquescent property of the earthy neutral salts, affords sufficient means of separating each kind of salt from the other; but this separation is impeded when there is much unctuous matter in the mixture.
2. Hence the purification of crude nitre depends principally on the separation of this substance.
3. The best method hitherto proposed, of freeing the nitre from its unctuous matter, seems to have been the addition of alum. But this method is not only too expensive, but there is reason to apprehend that the nitre may take up a portion of the vitriolic acid.
4. Mr. Gadolin undertook to purify nitre by charcoal powder, and relates the following experiments.
5. He put twelve pounds of very brown and moist crude nitre into a vessel, and found that a dark brown fluid had collected at the bottom of the vessel, amounting to about five ounces and a half. This he separated, and calls the mother-ley.
6. Four ounces of the nitre spread out upon bibulous paper, and dried in a moderate temperature of the air, weighed 7,15 half-ounces.
7. Half an ounce of crude nitre dissolved in water, gave, with a solution of silver, 0,0496 half-ounce of dry luna cornea.
8. Two ounces and a half of the crude nitre, dissolved in water, and supersaturated with vegetable alkali, gave a small quantity of a dark brown precipitate.
9. Half an ounce of the mother-ley gave, with a solution of silver, 0,368 half-ounce of luna cornea.

On filtering and evaporat-  
ing

ing the ley, a quantity of transparent prismatic crystals were produced. 10. From one ounce of the mother-ley precipitated by means of the vegetable-alkali, 0,092 half ounce of a coloured powder was obtained. The marine acid dissolved this powder with violent effervescence. The vitriolic acid effervesced in like manner with the precipitate, and left a considerable quantity of undissolved gypsum in a powdery state. This solution, when evaporated, afforded selenitic needles, and crystals of Epsom salt. 11. One ounce of the mother-ley evaporated to dryness by a gentle heat, left behind a dark brown mass, which was full of irregular cubic crystals, and weighed 0,625 half-ounce. 12. On smartly boiling for ten minutes, three ounces of the mother-ley, with four ounces of water, and three-fourths of an ounce of charcoal, the charcoal acquired an increase of one-fourth of an ounce in its weight. 13. Hence it follows that 100 parts of the crude saltpetre, which Mr. Gadolin employed, contained nearly  $9\frac{1}{2}$  per cent. of mother-ley, and three-sevenths more of marine acid than the same quantity of mother-ley. Again, according to experiment 7th, 100 parts of crude nitre contain as much marine acid as 4,96 parts of luna cornea; and according to experiment 9th, in  $9\frac{1}{2}$  parts of mother-ley, there was only as much marine acid as in three-fifth parts of luna cornea. 14. From experiments eleven and twelve it follows, that the ingredients in 100 parts of unrefined saltpetre were about 89 parts of pure nitre, three parts of muriated neutral salts, one part of unctuous matter, and six parts and a half of water, without reckoning the water of crystallization. 15. Mr. Gadolin being convinced of the possibility of purifying nitre by means of charcoal, made various experiments in order to ascertain what proportion of charcoal powder the saltpetre requires, and what phenomena would present themselves in the process. The proof of the absence of unctuous matter was ascertained by the facility of crystallization, and the greater quantity of crystals afforded; and the purity of the nitre was shewn by the test of the nitrous solution of silver. The results were according to the following Table:

	Crude nitre.	Charcoal powder.	Crystallized nitre.	Luna cornea, from a quarter of an ounce of the crystallized nitre.	Luna cornea, from 100 parts of crystallized nitre.	Luna cornea, from the lixivium, to 100 parts of pure nitre.
	Half ounces.	Half ounce.	Half ounce.	Half ounce.	Parts.	Parts.
1	32	2,5	19,5	0,0009	0,18	5,5
2	24	2,5	21,5	0,0011	0,22	3,
3	24	2,5	20,9	0,0013	0,26	13,
4	24	2,5	20,4	0,0017	0,34	16,
5	24	2,5	22,25	0,0025	0,50	20,
6	24	2,5	20,	0,0018	0,36	24,
7	24	2,5	21,5	0,0020	0,40	27,
8	0	1,	6,75	0,0070	1,4	90,
9	0	0	2,5	0,179	36,8	300,

From the preceding Table Mr. Gadolin observes, that we may see how little disposed the muriated salts are to unite with the nitre, when the lixivium is freed from its unctuous matter, and the crystallization is properly conducted: and that since the mother-ley is rendered fit for crystallization by means of charcoal



powder, there is reason to believe that charcoal powder might be very advantageously employed by the saltpetre makers in the first boilings of the impure ley. He adds, that in large purifications, much less than three-fourths of an ounce of charcoal powder to a pound of nitre, will, in all probability, be sufficient. That if in large purifications, the unctuous matter should be converted into scum, the charcoal powder will probably be separated from the ley by the desputation; in which case filtration will be unnecessary, and the expence attending this new process will then be very trifling. But even though the filtration should be found necessary, still he is persuaded that the expence, whatever it be, will be amply compensated by the greater purity of the nitre, and by the superior quality of the gunpowder prepared from it.

*Spermaceti.*

SPERMACETI. From the want of a correct table of reference to the *Annales de Chimie*, I did not discover the second memoir of Fourcroy, containing a chemical examination of the fatty substance into which the dead bodies in the burying-ground Des Innocens was converted. The reader will find a detail of the facts under the article *Spermaceti*, where this substance is erroneously said to be of the same nature as that animal product; a general opinion, founded as I suppose on the experiment mentioned in p. 865, and which may probably be true of such animal matters as are thus converted actually under water. The memoir of Mr. Fourcroy is of considerable length, nearly sixty pages, for which reason I shall not attempt to give a full account of every fact it exhibits, but shall select the leading facts as concisely as possible.

1. This substance is fused at a less degree of heat than that of boiling water, and may be purified by pressure through a cloth, which disengages a portion of fibrous and bony matter. 2. The process of destructive distillation by a very graduated heat was begun, but not completed on account of its tediousness, and the little promise of advantage it afforded. The products which came over, were water charged with volatile alkali, a fixable oil, concrete volatile alkali, and no elastic fluid during the time the operation was continued. 3. Fragments of the fatty matter, exposed to the air during the hot and dry summer of 1786, became dry, brittle, and almost pulverulent at the surface. On a careful examination, certain portions were observed to be semi-transparent, and more brittle than the rest. These possessed all the apparent properties of wax, and did not afford volatile alkali by distillation. 4. With water, this fatty matter exhibited all the appearances of soap, and afforded a strong lather. The dried substance did not form the saponaceous combination with the same facility or perfection as that which was recent. About two-thirds of this dried matter, separated from the water by cooling, and proved to be the semi-transparent substance resembling wax. This was taken from the surface of the soapy liquor, which being then passed through the filter, left a white soft shining matter which was fusible, and combustible. 5. Attempts were made to ascertain the quantity of volatile alkali in this substance, by the application of lime and of the fixed alkalis, but without success. For it was difficult to collect and appreciate the first portions which escaped, and likewise to disengage the last portions. The caustic volatile alkali, with the assistance of a gentle heat, dissolved the fatty matter, and the solution became perfectly clear and transparent at the boiling temperature of the mixture, which was at 185 degrees of Fahrenheit. 6. Vitriolic acid of the specific gravity of

was poured upon six times its weight of the fatty matter, and mixed by agitation. Heat was produced and a gas or effluvium of the most insupportable putrescence was emitted, which infected the air of an extensive laboratory for several days. Mr. Fourcroy says, that the smell cannot be described, but that it is one of the most horrid and repulsive that can be imagined. It did not however produce any indisposition either in himself or his assistants. By dilution with water, and the ordinary processes of evaporation and cooling properly repeated, vitriolic ammoniac and selenite were obtained. A substance was separated from the liquor, which appeared to be the waxy matter somewhat altered by the action of the acid. 7. The nitrous and marine acids were also applied, and afforded phenomena worthy of remark, but which for the sake of conciseness are here omitted. 8. Strong ardent spirit does not act on this matter at the ordinary temperature of the air. But by boiling it dissolves one third of its own weight, which is almost totally separable by cooling, as low as 55°. The spirit after this process affords by evaporation a portion of that waxy matter which is separable by acids, and is therefore the only portion soluble in cold ardent spirit. The quantity of fatty matter operated on, was four ounces, or 2304 grains, of which the boiling spirit took up the whole except 26 grains, which proved to be a mixture of 20 grains of ammoniacal soap, and six or eight grains of the phosphoric salts of soda and of lime. From this experiment, which was three times repeated with similar results, it appears that ardent spirit is well suited to afford an analysis of the fatty matter. It does not dissolve the neutral salts; when cold, it dissolves that portion of concrete animal oil of which the volatile alkali had flown off, and when heated it dissolves the whole of the truly saponaceous matter, which is afterwards completely separated by cooling. And accordingly it was found that a thin plate of the fatty matter, which had lost nearly the whole of its volatile alkali by exposure to the air for three years, was almost totally dissolved by the cold spirit.

The concrete oily or waxy substance obtained in these experiments constitutes the leading object of research, as being the peculiar substance with which the other well known matters are combined. It separates spontaneously by the action of the air, as well as by that of acids. These last separate it in a state of greater purity, the less disposed the acid may be to operate in the way of combustion. It is requisite therefore for this purpose, that the fatty matter should be previously diffused in 12 times its weight of hot water; and the marine or acetic acids are preferable to the vitriolic and nitrous. The colour of the waxy matter is grayish; and though exposure to the air, and also the action of the aerated marine acid, did produce an apparent whiteness, it nevertheless disappeared by subsequent fusion. No method was discovered by which it could be permanently bleached.

The nature of this wax, or fat, is different from that of any other known substance of the like kind. When slowly cooled after fusion, its texture appears crystalline or shivery like spermaceti; but a speedy cooling gives it a semi-transparency resembling wax. Upon the whole, nevertheless, it seems to approach more nearly to the former than to the latter of these bodies. It has less smell than spermaceti, and melts at 127 degrees of Fahrenheit. Spermaceti required 6° more of heat to fuse it. The spermaceti did not so speedily become brittle by cooling as the other substance. One ounce of alcohol of the strength between 39 and 40 degrees of Baumé's areometer, dissolved when boiling-hot 12 gros of this substance, but the same quantity in like circumstances dissolved only 30 or 36 grains of spermaceti. The separation of these matters was also remarkably,



remarkably different, the spermaceti being more speedily deposited, and in a much more regular and crystalline form. Volatile alkali dissolves with singular facility, and even in the cold, this concrete oil separated from the fatty matter; and by heat it forms a transparent solution, which is a true soap. But no excess of volatile alkali can produce such an effect with spermaceti.

M. De Fourcroy concludes his memoir with some speculations on this change to which animal substances in peculiar circumstances are subject. In the Modern Chemistry, soft animal matters are considered as a composition of the oxydes of hydrogen and carbonated azote, more complicated than those of vegetable matters, and therefore more incessantly tending to alteration. If then the carbone be conceived to unite with the oxygene, either of the water which is present or of the other animal matters, and thus escape in large quantities in the form of carbonic acid or fixed air; we shall perceive the reason why this conversion is attended with so great a loss of weight, namely, about nine tenths of the whole. The azote, a principle so abundant in animal matters, will form ammoniac by combining with the hydrogen; part of this will escape in the vaporous form, and the rest will remain fixed in the fatty matter. The residue of the animal matters deprived of a great part of their carbone, their oxygene and the whole of their azote will consist of a much greater proportion of hydrogen, together with carbone, and a minute quantity of oxygene. This, according to the theory of M. De Fourcroy, constitutes the waxy matter which, in combination with the ammoniac, forms the animal soap into which the dead bodies are thus converted.

Remarkably different, the spermaceti being more speedily deposited, and in a much more regular and crystalline form. Volatile alkali dissolves with singular facility, and even in the cold, this concrete oil separated from the fatty matter, and by heat it forms a transparent solution, which is a true soap. But no excess of volatile alkali can produce such an effect with spermaceti. M. De Lavoisier concludes his memoir with some speculations on the change to which animal substances in peculiar circumstances are subject. In the Modern Chemistry, for animal matters are considered as a composition of the oxides of hydrogen and carbon, more complicated than those of

## ERRATA.

Page 6, line 22, for *excepting that they do*, read *excepting that it does*.—P. 13, l. 15, for *resembles*, read *resemble*.—P. 29, l. 45, for *grinding in a mortar*, read *grinding it in a mortar*.—P. 29, l. 50, for *till be water*, read *till the water*.—P. 40, l. 43, for *ETHER NITROUS*, read *ETHER only*.—P. 45, l. 15, for *liquid phosphorous*, read *liquid acid of phosphorus*.—P. 101, l. 44, for *however but that men*, read *however that men*.—P. 104, l. 13, for *if not*, read *if it does*.—P. 125, l. 26, after *FERMENTATION*, read also *PUTREFACTION*.—P. 145, l. 42, for *have not as yet*, read *did not*.—P. 172. Mr. Morveau has since published some corrections of this table. They are, Ponderous earth and vitriolic acid 66. Ponderous earth and acetic acid 28. Marine acid and the following, viz. min. alk. 31; lime 24; vol. alk. 21; magnesia 22; argill. earth 18.—P. 193, l. 17, for *the beam will be*, read *the beam will weigh*.—P. 204, l. 11, for *some*, read *lime*.—P. 228, l. 34, for *here* read *Bengal*.—P. 239, l. 9, for *were*, read *are*.—P. 267, l. 35, for *acid water*, read *acid, water*.—P. 290, l. 46, for *imply*, read *imply*.—P. 298, l. 23, for *they serve as intermedium*, read *for they serve as an intermedium*.—P. 309, l. 45, for *coloured*, read *calcined*.—P. 351, l. 16, for *a state of perfection*, read *its state of perfection*.—P. 351, l. 44, for *referrible*, read *referable*.—P. 371, l. 48, for *or is that which causes it*, read *and is that which causes it*.—P. 373, l. 14, for *have been observed*, read *has been observed*.—P. 375, l. 9, for *that the expansions*, read *shows that the expansions*.—P. 398, l. 50, for *PHLOGISTICS*, read *PHLOGISTON*.—P. 406, l. 7, for *vital air*, read *vital air*.—P. 416, l. 30, for *falls*, read *salts*.—P. 424, l. 24, for *JELLY*, read *GELLY*.—P. 428, l. 10, for *Bartbolate*, read *Bertbollet*.—P. 485, l. 14, for *precipitating*, read *precipitate*.—P. 587, l. 41 and 48, for *tuyere*, read *tuyere*.—P. 627, l. 17, for *litruus*, read *litmus*.—P. 628, l. 17, after *grains*, dele *as we shall presently find*.—P. 641, l. 33, for *maintained*, read *maintain*.—P. 642, l. 1, for *us then say, they*, read *us then, say they*.—P. 655, l. 10, for *resinous*, read *urinous*.—P. 760, l. 6, for *latter*, read *fiery stream*.—P. 765, l. 30, for *Rork's*, read *Born's*.—P. 839, in the note, for *Keir*, read *Here*.—P. 851, l. 30, for *ALKALINE*, read *ALKALI*.—P. 983, l. 24, for *said*, read *sett*.

## TO THE BINDER.

There are Five Plates, which are to be placed at the end.  
The First Volume is to end with Signature 4 D, Page 576.



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THE END.

Fig 1.



Fig 2.



Fig 3.

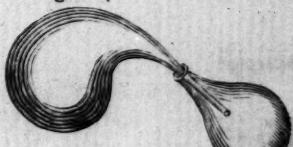


Fig 4.



Fig 5.



Fig 6.

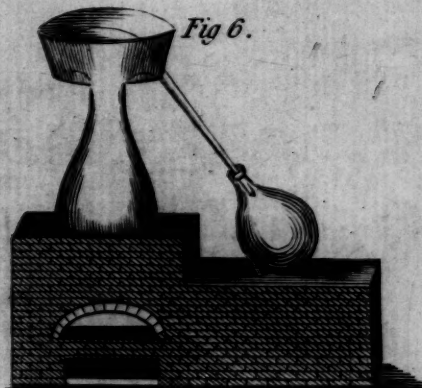


Fig 14.

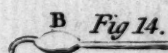


Fig 16.



Fig 20.



Fig 21.



Fig 15.

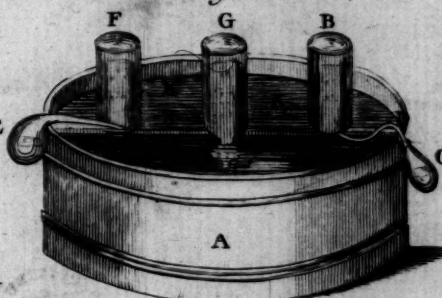


Fig 18.

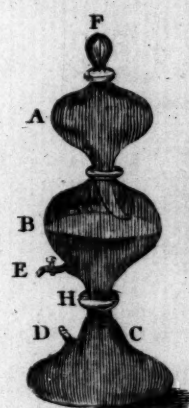


Fig 19.



Fig 22.

Fig 12.

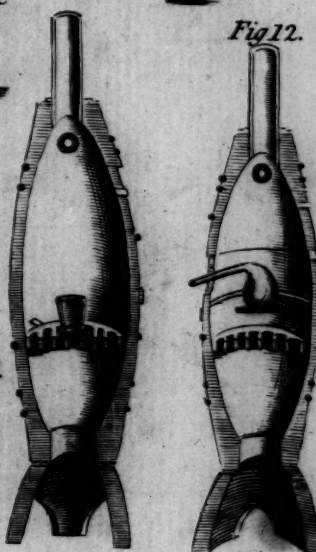


Fig 10.

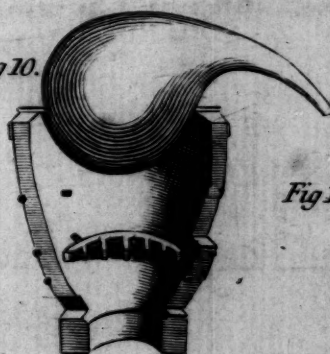


Fig 11.



Fig 7.

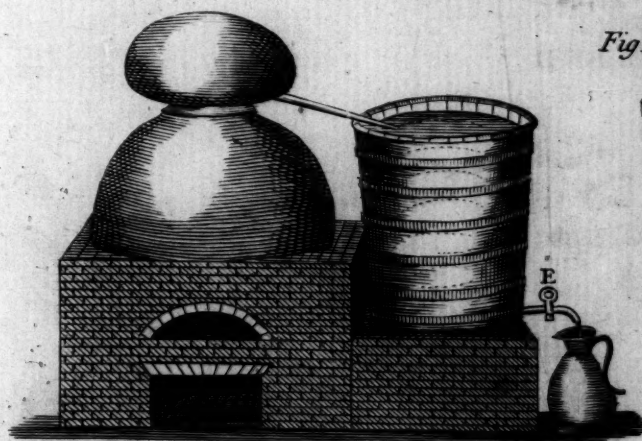


Fig 13.



Fig 9.

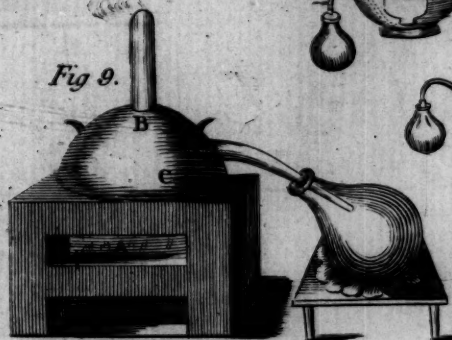


Fig 17.



Fig 8.

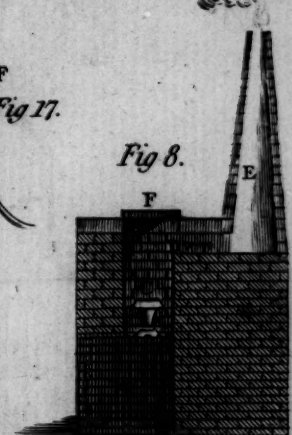
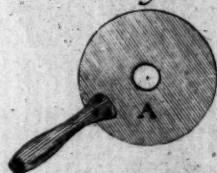
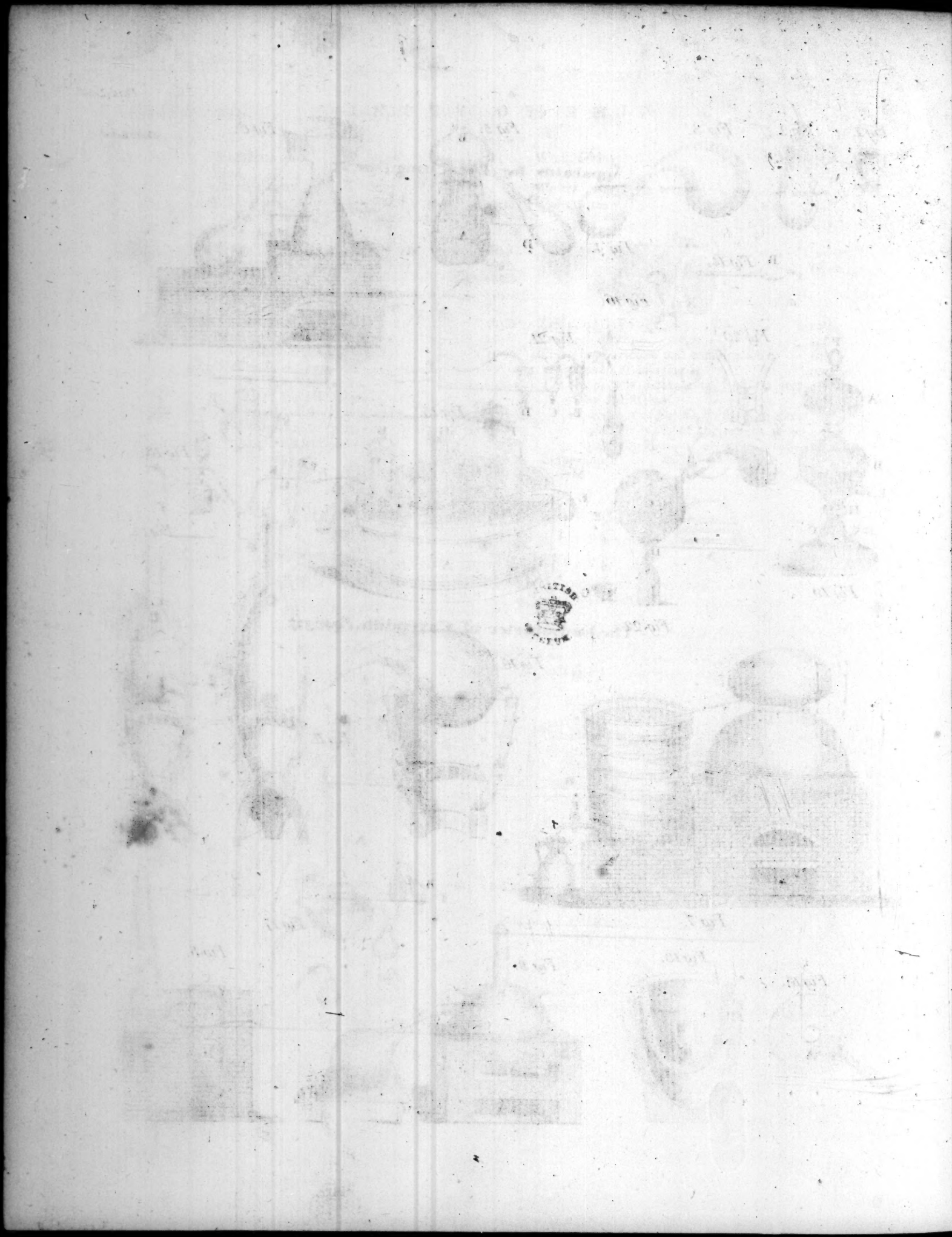


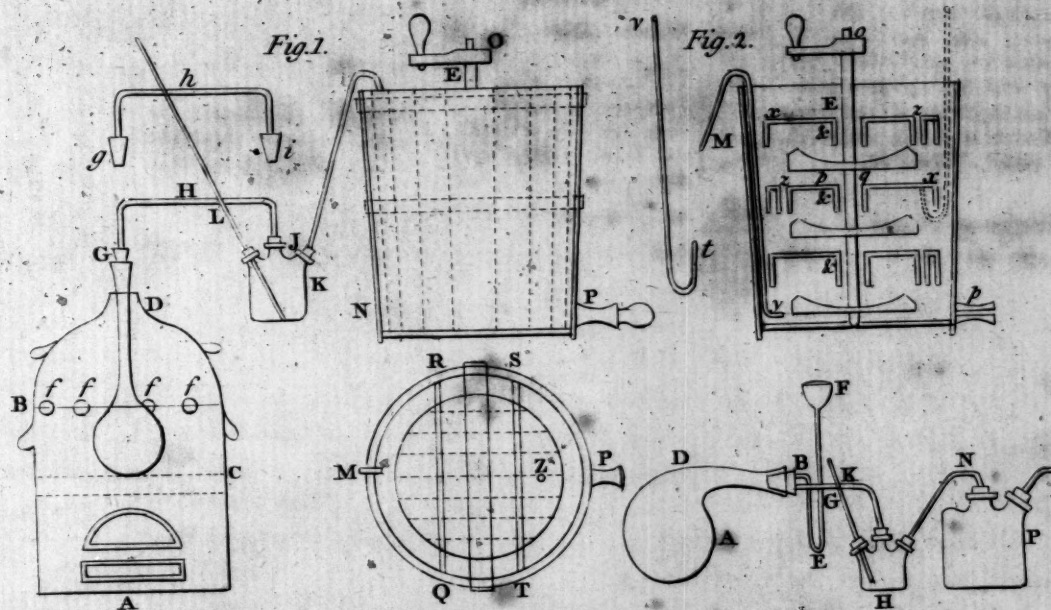
Fig 13.



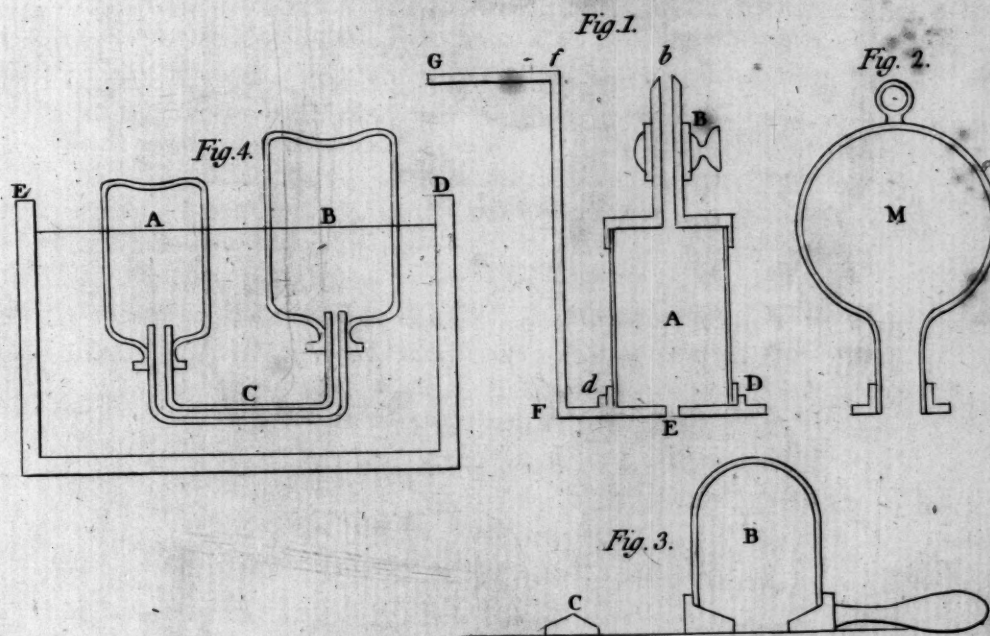




Apparatus for Bleaching Page 25.



The Eudiometer of Cavendish. Page 327.





# I. TABLE OF THE CHARACTERS TO BE MADE

*Simple Substances which can exist in the aeriform state in the ordinary temperature of the Atmosphere, and which entering into the composition of an infinity of substances demand a great simplicity of their Characters.*

*Alkalies which are as yet considered as simple Substances*

*Simple Earths*

*Combustible Simple Substances, commonly called Inflamable Substances.*

*Light.*

*Caloric. Matter of Heat.*

*Oxygen. Base of Vital Air.*

*Azot. Base of Nitric Air, or Mofette.*

*Characters to express such new and simple Substances as may be discovered.*

*Potash. Caustic fixed Alkali.*

*Soda. Caustic Mineral Alkali.*

*Barytes. Ponderous earth.*

*Lime. Calx.*

*Magnesia.*

*Alumina. Argillaceous earth.*

*Silice, Quartz.*

*Hydrogen. Base of Inflamable Air.*

*Carbon. or pure Charcoal.*

*Sulphur.*

*Phosphorus.*

*Characters to express such new combustible substances as will be discovered.*

## METALLIC SUBSTANCES.

*Metals reducible by heat alone.*

*A metal in the liquid State in the ordinary temperature of the atmosphere.*

*Malleable Metals.*

*Metals not malleable.*

*Acidifiable Metals.*

(P)	Platina.
(O)	Gold. Aurum.
(A)	Silver. Argentum.
(H)	Mercury. Hydrargyrum.
(S)	Tin. Stannum.
(C)	Copper. Cuprum.
(P)	Lead. Plumbum.
(F)	Iron. Ferrum.
(Z)	Zink. Zincum.
(M)	Manganese. Magnesium.
(N)	Nickel. Nicolum.
(B)	Bismuth. Bismuthum.
(St)	Antimony. Stibium.
(K)	Cobalt. Kobaltum.
(As)	Arsenic. Arsenicum.
(M)	Molybden. Molybdenum.
(T)	Tunstein. Tunstenum.

## II. TABLE. COMBINATIONS OF CALORIC. with different Simple Substances, producing the Solid, Liquid, and Aeriform States.

	Solid.	Liquid.	Aeriform.		Solid.	Liquid.	Aeriform.		Solid.	Liquid.	Aeriform.
Azot.	/	✓	✓	Copper.	(C)	(C)	(C)	Pyro-tartareous Radical.	(F)	(F)	(F)
Potash.	(P)	(P)	(P)	Lead.	(P)	(P)	(P)	Oxalic Radical.	(O)	(O)	(O)
Soda.	(S)	(S)	(S)	Iron.	(F)	(F)	(F)	Gallie Radical.	(G)	(G)	(G)
Barytes.	(B)	(B)	(B)	Zink.	(Z)	(Z)	(Z)	Citric Radical.	(C)	(C)	(C)
Lime.	(V)	(V)	(V)	Manganese.	(M)	(M)	(M)	Malic Radical.	(M)	(M)	(M)
Magnesia.	(W)	(W)	(W)	Nickel.	(N)	(N)	(N)	Benzoic Radical.	(Bz)	(Bz)	(Bz)
Alumina.	(A)	(A)	(A)	Bismuth.	(B)	(B)	(B)	Pyro-lignic Radical.	(E)	(E)	(E)
Silice.	(S)	(S)	(S)	Antimony.	(Sb)	(Sb)	(Sb)	Camphoric Radical.	(Cp)	(Cp)	(Cp)
Hydrogen.	(H)	(H)	(H)	Arsenic.	(As)	(As)	(As)	Lactic Radical.	(L)	(L)	(L)
Carbon.	(C)	(C)	(C)	Molybden.	(M)	(M)	(M)	Saccho-lactic Radical.	(Sl)	(Sl)	(Sl)
Sulphur.	(S)	(S)	(S)	Tunstein.	(T)	(T)	(T)	Formic Radical.	(Fm)	(Fm)	(Fm)
Phosphorus.	(P)	(P)	(P)	Muriatic Radical.	(M)	(M)	(M)	Prussic Radical.	(P)	(P)	(P)
Gold.	(O)	(O)	(O)	Boracic Radical.	(B)	(B)	(B)	Sebacic Radical.	(Sb)	(Sb)	(Sb)
Platina.	(P)	(P)	(P)	Fluoric Radical.	(F)	(F)	(F)	Bombic Radical.	(Bb)	(Bb)	(Bb)
Silver.	(A)	(A)	(A)	Succinic Radical.	(S)	(S)	(S)	Lithic Radical.	(L)	(L)	(L)
Mercury.	(H)	(H)	(H)	Acetous Radical.	(A)	(A)	(A)	Ether.	(E)	(E)	(E)
Tin.	(S)	(S)	(S)	Tartareous Radical.	(T)	(T)	(T)	Alkohol.	(A)	(A)	(A)

### III<sup>d</sup> TABLE. THE KNOWN COMBINATIONS OF OXYGEN & CALORIC WITH DIFFERENT SUBSTANCES

Nitrous Gas.	Concrete Oxygenated Muriatic Acid.	Liquid Sebacic Acid.
Nitrous Acid Gas.	Concrete Boracic Acid.	Liquid Bombic Acid.
Nitrous Acid.	Fluoric Acid Gas.	Oxyd of Turstein.
Nitric Acid.	Concrete Succinic Acid.	Turstic Acid.
Oxygenated Nitric Acid.	Liquid tartareous Acid.	Oxyd of Molybden.
Ice.	Concrete tartareous Acid.	Concrete Molybdic Acid.
Water.	Liquid Pyro-tartareous Acid.	Oxyd of Arsenic.
Vapor of Water.	Liquid Acetous Acid.	Concrete Arsenic Acid.
Carbonic Acid Gas.	Acetous Acid Gas.	Oxyd of Cobalt.
Sulphureous Oxyd Gas.	Liquid Acetic Acid.	Oxyd of Antimony.
Sulphureous Acid Gas.	Concrete Oxalic Acid.	Oxyd of Bismuth.
Sulphureous Acid.	Liquid Gallic Acid.	Oxyd of Nickel.
Liquid Sulphuric Acid.	Liquid Citric Acid.	Oxyd of Manganese.
Concrete Sulphuric Acid.	Liquid Malic Acid.	Oxyd of Zink.
Concrete Phosphorous Acid.	Concrete Benzoic Acid.	Oxyd of Iron.
Liquid Phosphorous Acid.	Liquid Pyro-ligneous Acid.	Oxyd of Lead.
Liquid Phosphoric Acid.	Liquid Pyro-mucous Acid.	Oxyd of Copper.
Liquid Muriatic Acid.	Concrete Camphoric Acid.	Oxyd of Tin.
Muriatic Acid Gas.	Liquid Lactic Acid.	Oxyd of Mercury.
Oxygenated Muriatic Acid Gas.	Concrete Saccho-lactic Acid.	Oxyd of Silver.
Liquid Oxygenated Muriatic Acid.	Liquid Formic Acid.	Oxyd of Gold.
	Prussic Acid Gas.	Oxyd of Platina.



TABLE IV. COMBINATIONS OF TWO SUBSTANCES.  
Caloric forms a third in some of these Compositions.

Ammoniacal Gas.	⌒	Sulphuret of Alumine.	⌒	Sulphuret of Antimony.	⌒	Amalgam of Silver.	⌒
Concrete Ammoniac.	⌒	Sulphuret of Gold.	⌒	Sulphuret of Cobalt.	⌒	of Copper.	⌒
Carbonated Azotic Gas.	⌒	Sulphuret of Silver.	⌒	Sulphuret of Arsenic.	⌒	of Tin.	⌒
Sulphurated Azotic Gas.	⌒	Sulphuret of Mercury.	⌒	Sulphuret of Molybden.	⌒	Alloy of Tin & Copper.	⌒
Carbonated Hydrogen Gas.	⌒	Sulphuret of Tin.	⌒	Phosphuret of Lead.	⌒	of Tin & Lead.	⌒
Sulphurated Hydrogen Gas.	⌒	Sulphuret of Copper.	⌒	Phosphuret of Iron.	⌒	of Iron & Manganese.	⌒
Phosphorated Hydrogen Gas.	⌒	Sulphuret of Lead.	⌒	Alloy of Platina & Gold.	⌒	of Iron & Nickel.	⌒
Sulphuret of Potash.	⌒	Sulphuret of Iron.	⌒	of Platina & Silver.	⌒	Carburet of Iron.	⌒
Sulphuret of Soda.	⌒	Sulphuret of Zink.	⌒	of Gold & Silver.	⌒		
Sulphuret of Barytes.	⌒	Sulphuret of Nickel.	⌒	of Gold & Copper.	⌒		
Sulphuret of Lime.	⌒	Sulphuret of Bismuth.	⌒	Amalgam of Gold.	⌒		

TABLE V. NEUTRAL SALTS COMPOSED OF THREE SUBSTANCES.

Caloric is not expressed, because they are all supposed to be in the solid state. The Ammoniacal State are composed of four Substances.

Calcareous Acetat.	⌒	Calcareous Camphorat.	⌒	Acidulous Oxalat of Potash.	⌒	Sulphat of Lime.	⌒
Acetat of Alumine.	⌒	Citrat of Soda.	⌒	Phosphat of Potash.	⌒	Acidulous Sulphat of Alumine.	⌒
Acetat of Magnesia.	⌒	Ammoniacal Citrat.	⌒	Phosphat of Soda.	⌒	Sulphat of Alumine.	⌒
Acetat of Potash.	⌒	Calcareous Citrat.	⌒	Ammoniacal Phosphat.	⌒	Sulphat of Alumine with excess of base.	⌒
Acetat of Soda.	⌒	Fluat of Potash.	⌒	Phosphat of Lime.	⌒	Sulphat of Magnesia.	⌒
Acetat of Copper.	⌒	Fluat of Ammoniac.	⌒	Phosphat of Iron.	⌒	Sulphat of Silver.	⌒
Acetat of Iron.	⌒	Fluat of Lime.	⌒	Phosphite of Soda.	⌒	Sulphat of Mercury.	⌒
Ammoniacal Acetite.	⌒	Formiat of Soda.	⌒	Prussiat of Iron.	⌒	Sulphat of Tin.	⌒
Acetite of Potash.	⌒	Ammoniacal Formiat.	⌒	Pyro tartrite of Potash.	⌒	Sulphat of Copper.	⌒
Calcareous Acetite.	⌒	Calcareous Formiat.	⌒	Pyro mucite of Soda.	⌒	Sulphat of Lead.	⌒
Bombiat of Potash.	⌒	Lactat of Soda.	⌒	Pyro lignite of Ammoniac.	⌒	Sulphat of Iron.	⌒
Ammoniacal Bombiat.	⌒	Ammoniacal Lactat.	⌒	Saccho-lat of Potash.	⌒	Sulphat of Zink.	⌒
Calcareous Bombiat.	⌒	Lactat of Lime.	⌒	Sebat of Soda.	⌒	Sulphat of Manganese.	⌒
Carbonat of Potash.	⌒	Gallat of Potash.	⌒	Sulphite of Potash.	⌒	Sulphat of Nickel.	⌒
Carbonat of Soda.	⌒	Malat of Potash.	⌒	Sulphat of Potash.	⌒	Sulphat of Bismuth.	⌒
Ammoniacal Carbonat.	⌒	Muriat of Potash.	⌒	Acidulous Sulphat of Potash.	⌒	Sulphat of Antimony.	⌒
Calcareous Carbonat.	⌒	Muriat of Soda.	⌒	Sulphat of Potash with excess of base.	⌒	Sulphat of Cobalt.	⌒
Barytic Carbonat.	⌒	Ammoniacal Muriat.	⌒	Sulphat of Soda.	⌒	Sulphat of Arsenic.	⌒
Magnesian Carbonat.	⌒	Barytic Muriat.	⌒	Acidulous Sulphat of Soda.	⌒	Sulphat of Molybden.	⌒
Carbonat of Iron.	⌒	Muriat of Iron.	⌒	Sulphat of Soda with excess of base.	⌒	Sulphat of Turstein.	⌒
Benzoat of Potash.	⌒	Oxygenated Muriat of Soda.	⌒	Sulphat of Ammoniac.	⌒	Succinat of Potash.	⌒
Ammoniacal Benzoat.	⌒	Nitrat of Potash, or Nitre.	⌒	Acidulous Sulphat of Ammoniac.	⌒	Arseniat of Potash.	⌒
Calcareous Benzoat.	⌒	Nitrat of Soda.	⌒	Sulphat of Ammoniac with excess of base.	⌒	Acidulous Arseniat of Potash.	⌒
Borat of Soda.	⌒	Ammoniacal Nitrat.	⌒			Arseniat of Potash with excess of base.	⌒
Ammoniacal Borat.	⌒	Barytic Nitrat.	⌒			Molybdat of Soda.	⌒
Calcareous Borat.	⌒	Nitrat of Silver.	⌒			Ammoniacal Turstat.	⌒
Camphorat of Potash.	⌒	Nitrite of Potash.	⌒			Calcareous Turstat.	⌒
Ammoniacal Camphorat.	⌒	Oxalat of Potash.	⌒			Lithiat of Potash.	⌒

TABLE VI. THE ANCIENT CHEMICAL SIGNS or CHARACTERS.

$\Delta$ Fire.	$\text{☿}; \text{♂}$ Regulus of Antimony.	c. $\ominus^{\Delta}$ Caustic vol. Alkali.	$\text{☿}$ Caput Mortuum.
$\triangle$ Air.	$\text{○} \text{---} \text{○}$ Arsenic	$\Psi$ Potash.	$\text{○}$ A Powder.
$\nabla$ Water.	$\text{○} \text{---} \text{○}$ Regulus of Arsenic	$+$ ; $\text{---}$ ; $+$ ; Acids	$\text{E}$ Ashes.
$\nabla$ Earth.	K Cobalt.	$\text{✱}$ ; Vinegar.	B. A Bath.
f. $\Delta$ Fixable Air.	N Nickel.	$\text{⊕}$ ; $>$ $\text{⊕}$ ; Nitric Acid.	BM; MB; Water-bath.
m. $\Delta$ Mephitic Air.	S.M. Metallic Substances.	$\text{⊕}$ ; $>$ $\text{⊕}$ ; Nitrous Acid.	A.B. Sand-bath.
$\nabla$ Clay.	C Calc.	$\text{⊕}$ ; $>$ $\text{⊕}$ ; Marine Acid.	V.B. Vapor-bath.
$\nabla$ Gypsum	$\text{○} \text{---} \text{○}$ Orpiment.	F. A; Aquafortis.	X An Hour.
$\nabla$ ; c. $\nabla$ ; Calcareous Earth	$\text{♂}$ Cinnabar.	R. R; Aqua Regia.	$\text{○}$ A Day.
$\Psi$ ; CV; T. Quicklime	L.C. Lapis Calaminaris.	$\text{♂}$ Vol. Sulphureous Acid.	$\text{○}$ A Night.
$\Sigma$ Friable, or, Siliceous Earths.	$\text{⊗}$ Tutty.	$\text{♂}$ Phosphoric Acid.	$\text{☒}$ A Month.
$\Sigma$ Fluoks, or Fusible Earths.	$\text{⊕}$ Vitriol.	V. Wine.	aaa $\Delta$ Amalgam.
X Talk.	$\text{⊕}$ ; $\text{⊕}$ ; Sea Salt.	$\nabla$ Spirit of Wine.	$\text{♂}$ ; $\text{♂}$ To Distill.
MV Magnesia.	$\text{⊕}$ ; $\text{⊕}$ ; Sal Gem.	$\nabla$ Rectified Spirit of Wine.	$\text{=}$ To Sublime.
AV; $\text{⊕}$ ; Earth of Alum.	$\text{⊕}$ Nitre.	$\text{AE}$ Ether.	$\text{=}$ To Precipitate.
$\text{⋯}$ Sand.	$\text{☐}$ ; $\text{☐}$ ; Borax.	$\nabla$ Lime Water.	$\text{☐}$ A Retort.
$\text{○}$ Gold.	S.S. Sedative Salt.	$\text{☐}$ Urine.	XX An Alembic.
$\text{⊕}$ ; $\text{♂}$ ; Silver.	$\text{✱}$ ; $\text{⊕}$ ; Sal Ammoniac.	$\text{⋯}$ ; $\text{⊕}$ ; $\text{⊕}$ ; $\text{♂}$ ; Oil.	$\text{+}$ ; $\text{+}$ ; A Crucible.
$\text{♀}$ Copper.	$\text{○}$ ; $\text{☐}$ ; Alum.	$\Delta$ ; $\text{⋯}$ ; Essential Oil.	SSS. Stratum Super-Stratum.
$\text{♀}$ Tin.	$\text{♀}$ Tartar.	$\nabla$ Fixed Oils	C.C. Cornu Ceryi. Hartshorn.
$\text{♂}$ Lead.	$\text{☐}$ ; $\text{♂}$ ; Alkali.	$\Delta$ Sulphur.	$\text{☐}$ A Bottle.
$\text{♀}$ Mercury.	$\text{⊕}$ ; $\text{⊕}$ ; Fixed Alkali.	$\text{⊕}$ Hepar of Sulphur	$\text{gr. i.}$ A Grain.
$\text{♂}$ Iron.	$\text{⊕}$ ; $\text{⊕}$ ; Volatile Alkali.	$\Delta$ Phosphorus.	$\text{℥i.}$ A Scruple.
$\text{Z}$ Zinc.	m. $\text{⊕}$ Mild fixed Alkali.	$\Delta$ Phlogiston.	$\text{℥i.}$ A Dram.
B; W Bismuth.	c. $\text{⊕}$ Caustic fixed Alkali.	$\text{⊕}$ Soap.	$\text{℥i.}$ An Ounce
$\text{♂}$ Antimony.	m. $\text{⊕}$ Mild vol. Alkali.	$\text{⊕}$ Verdegrise.	$\text{℔i.}$ A Pound.
		$\text{---} \text{○}$ Glass.	dwt. i. A Penny weight.

TABLE VII. THE CHEMICAL SIGNS AS THEY OCCUR IN THE WRITINGS OF BERGMAN.

ACIDS.		EARTHS.	METALLIC CALCES.
1. + $\text{⊕}$ Vitriolic.	16. + $\text{⊕}$ Amber.	29. $\text{♀}$ Pure Ponderous.	44. $\text{♀}$ $\text{⊕}$ Gold.
2. + $\text{⊕}$ $\Delta$ Phlogisticated.	17. + $\text{⊕}$ Sugar of Milk.	30. $\text{♀}$ Pure calcareous Lime.	45. $\text{♀}$ $\text{⊕}$ Platina.
3. + $\text{⊕}$ Nitrous.	18. $\text{✱}$ Acetous. distilled.	31. $\text{♀}$ Pure Magnesia.	46. $\text{♀}$ $\text{⊕}$ Silver.
4. + $\text{⊕}$ $\Delta$ Phlogisticated.	19. + $\text{⊕}$ Milk.	32. $\nabla$ Pure Argillaceous.	47. $\text{♀}$ $\text{♀}$ Mercury.
5. + $\text{⊕}$ Marine.	20. + $\text{f}$ Ants.	33. $\nabla$ Pure Siliceous.	48. $\text{♀}$ $\text{♂}$ Lead.
6. + $\text{⊕}$ $\nabla$ Dephlogisticated.	21. + $\text{⊕}$ Fat.	34. $\nabla$ Water.	49. $\text{♀}$ $\text{♀}$ Copper.
7. $\nabla$ Aqua regia.	22. + $\text{♂}$ of Phosphorus.	35. $\Delta$ Vital Air.	50. $\text{♀}$ $\text{♂}$ Iron.
8. + $\text{f}$ of Fluor.	23. + $\text{♂}$ Perlutum.	36. $\Delta$ Phlogiston.	51. $\text{♀}$ $\text{♀}$ Tin.
9. $\text{⊕} \text{---} \text{⊕}$ Arsenic.	24. + $\text{⊕}$ of Prussian blue.	37. $\Delta$ Matter of Heat.	52. $\text{♀}$ $\text{⊕}$ Bismuth.
10. + $\text{☐}$ Borax.	25. $\Delta$ Aerial.	38. $\Delta$ Sulphur.	53. $\text{♀}$ $\text{♂}$ Nickle.
11. + $\text{⊕}$ Sugar.		39. $\text{⊕}$ $\Delta$ Salina Hepar.	54. $\text{♀}$ $\text{⊕}$ Arsenic.
12. + $\text{☐}$ Tartar.	ALKALIS	40. $\nabla$ Spirit of Wine.	55. $\text{♀}$ $\text{⊕}$ Cobalt.
13. + $\text{⊕}$ Sorrel.	26. $\text{⊕}$ $\text{♀}$ Pure fixed Vegetable.	41. $\text{⊕}$ Ether.	56. $\text{♀}$ $\text{⊕}$ Zinc.
14. + C Lemon.	27. $\text{⊕}$ $\text{♀}$ Pure fixed Mineral.	42. $\text{⊕}$ Essential Oil.	57. $\text{♀}$ $\text{♂}$ Antimony.
15. + $\text{+}$ Benzoin.	28. $\text{⊕}$ $\text{♀}$ Pure Volatile.	43. $\text{⊕}$ Unctuous Oil.	58. $\text{♀}$ $\text{⊕}$ Manganese.
			59. $\text{♀}$ $\text{♂}$ Siderite.